CONCEIVING NATURE AFTER ARISTOTLE KANT AND HEGEL

THE PHILOSOPHER'S GUIDE TO THE UNIVERSE

Richard Dien Winfield

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Conceiving Nature after Aristotle, Kant, and Hegel

The Philosopher's Guide to the Universe

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In memory of my father-in-law, Suresh Gupta (1930–2016)

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1. Introduction

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The following is an exploration of forbidden delights. We are going to be examining what the current academy will not allow to be addressed, something considered so inappropriate as not to qualify for any serious study. Our tabooed subject is the philosophy of nature , which the reigning orthodoxy has sought to put into oblivion by supplanting it with the philosophy of science.

Once upon a time the science of nature was the philosophy of nature . For many centuries there was no distinction between the two, but since early modern times, a science of nature has set itself apart from philosophy. More recently academia has become dominated by the view that the philosophy of nature is a meaningless enterprise and that all reason can do with respect to nature is engage in a philosophy of science, reflecting on the methodology of empirical investigations of the universe. This substitution of philosophy of science for philosophy of nature is grounded in the assumption that when it comes to knowledge of determinate objects, reason is utterly powerless and instead must hand over all efforts to know specific subject matter to sciences guided by observation. Incapable of knowing nature by reason, all philosophy can do is reflect on the operations of empirical science.

Reason is here regarded to be merely analytic in character. Allegedly reason is incapable of generating any new content of its own, let alone of relating conceptual determinations to anything else. All reason can supposedly do is analyze what is contained within given concepts and distinguish what is and is not identical with them. Consequently, when philosophers reflect upon the results of empirical observation they can do nothing more than certify to what degree scientific theory is coherent and consistently applied to its data. As for reason itself, it is reduced to a barren scaffold that can be understood in terms of a formal logic, which regards thought as not having any intrinsic content, as always being about matters which lie outside thought. Therefore the logic of thinking is formal, a logic of thinking any content whatsoever insofar as there are no contents intrinsic to thought. On these terms, all thought can know in understanding itself is its formal identity, that it is at one with itself in whatever content it engages in thinking. Thought may analyze independently given contents, but thought has no power to generate any contents of its own, to relate different contents to one another, be they conceptual or non-conceptual, or to secure any relationship between concepts and what is other than thought.

Such is the prevailing view that rules the philosophical academy. Under its sway, there are no courses in philosophy of nature ; there are only courses in the philosophy of science. Nonetheless, this reduction of reason to an empty scaffold, reducing philosophy to an analysis of

empirical givens or empirically available linguistic usage, is itself incoherent. Although it relegates reasoning to formal logic, it makes a very non-formal claim about the status of reason, about the inability of reason to do anything more than be an operation of formal self-identity. The prevailing orthodoxy positively affirms what reason is and what reason can or cannot do. Offering these synthetic claims without qualification, it does something that its own description of reason precludes.

This difficulty reflects how abandoning the synthetic power of reason can never be coherently advanced. One can never be cured of the urge to do philosophy, the urge to obtain new truths through reason alone, but the fact that one can never be cured of doing philosophy does not mean that reason can apprehend what nature is.

Nonetheless, there has been a rampant tendency to not only regard reason as empty and powerless, but treat philosophy as if it were just another positive science, sharing the character of an empirical inquiry. A science is positive in that, on the one hand, it addresses a given subject matter whose character is taken for granted and, on the other hand, presupposes that it has access to what it is investigating. These dual presuppositions, of the boundaries of one's subject matter and of the method one employs, might appear to be inescapable. After all, if one does not have any given topic to confront or any given access to it, it is not clear how one can begin at all undertaking a determinate science. The mere fact, however, that any positive science operates with these dual presuppositions of content and method means that all of its results are doubly conditioned. They are relative to whatever boundaries, whatever preconceptions of its subject matter the science begins with, as well as to whatever methodology it embraces and whatever access it presumes to have with regards to its subject matter. In these respects, positive sciences remain in the realm of opinion, pursuing a conditioned, relative enterprise that can never purport to make any unqualified claims about anything.

Philosophers have never been able to be satisfied with the labors of opinion of positive science. Philosophers cannot take the boundaries of their subject matter for granted nor take for granted their access to whatever it is they should be addressing, because these, after all, are themselves philosophical questions. What philosophy itself should be addressing is as much a philosophical problem as is what approach philosophy should take. If philosophy is to get at truth without qualification it cannot make presuppositions about its subject matter or about its method. Rather, these are themselves matters that philosophy must establish through and within its own investigation. Recognition of this predicament has driven philosophy to be autonomous rather than be beholden to given authority.

One of the fundamental ways in which philosophy has attempted to free itself of the hold of given content boundaries and of dependence upon a given method is to try to get at "what is" immediately, what is absolutely, what is not a construction or a convention or something relative to any other factor. Assumptions are to be overcome by getting at that which is genuinely not mediated but fundamentally immediate, that which can be said to be what comes first. This involves getting at what is "by nature " as opposed to what is by convention. By finding what is immediately as opposed to what is mediated, one can, it seems, arrive at a subject matter that would not have the relativity that afflicts any enterprise of positive science.

Moreover, if one is to get at what is genuinely immediate, what comes first without further qualification, one equally would need to access it in a way that is equally unmediated. To avoid the relativizing mediations of construction and distorted transmission, one needs to apprehend what is by nature in a manner that is itself completely direct, completely devoid of any interpretation or anything of that sort. In order to uncover what is not mediated by anything else

but is utterly original and immediate, what might be considered to be by nature and be what mediates everything else, one must forego any cognitive operation that mediates its object. What is by nature can only be apprehended, it would seem, in a contemplative rather than constructive manner, a contemplation that is intuitive, directly relating to its object.

Such is the driving rationale of that mode of doing philosophy that seeks to escape the hold of opinion and convention by intuiting what is without further qualification, what is immediate, what comes first, what is by nature the fundamental basis of the universe. As the history of philosophy has made evident, this search for the first principle of being engenders manifold competing candidates for what is immediately intuited, raising the question, how can one determine what qualifies as the privileged first principle?

This presents a daunting problem since what comes first cannot owe its primacy to any other factor. Nothing else can ground the first principle without rendering the latter something mediated and relative to what offers it support, which then takes the throne of "firstness" for itself. Hence, no reasons can be provided from which one could derive the candidate for what is immediate and establish some particular factor to be undetermined by any other thing but determinative of everything else and in that respect to uniquely occupy the position of first principle.

If the first principle cannot be identified by appeal to anything that grounds its primacy, can what comes first be uncovered by working in the opposite direction? Can we certify its privileged position by showing that everything else indeed derives from it? Can we, however, know what everything else is in its totality without already knowing what is the first principle? That principle, after all, is what we have to know to comprehend in full anything else that is not first. Moreover, how could we know with any certainty that everything without exception derives from that privileged factor as opposed to anything else?

In either direction, looking behind or looking forwards, we face insoluble problems in trying to secure what comes first. In addition, there is the basic difficulty of making immediate appeal to "what is" and taking philosophy to first consist in ontology. Not only is there ineluctable controversy concerning what candidates provide anything like a first principle, but there is always the possibility of calling into question anyone's claims about "what is" by challenging the authority of the knowing that is being employed. Should not that cognition be investigated before accepting any of its claims about being?

Before following this turn in philosophical strategy and examining its implications for conceiving the universe, it is worth asking how nature gets addressed by the first fundamental approach in philosophy, which makes ontology fundamental. Here the investigation of being is first philosophy, building the anchor for any further investigation of particular spheres of being, such as nature and mind. Nature , as a particular ontological domain, is not what is meant by that which generally is distinguished from convention in the attempt to get at what is not relative or conditioned. Admittedly, we are here concerned with getting at what nature is by nature , as opposed to how nature may be constructed by particular conventions of inquiry, each of which has its own particular perspective and bias.

How does the particular ontological domain of nature become thinkable on the basis of the fundamental philosophical approach that takes ontology as first philosophy? Is there a specific way of conceiving nature that follows from this strategy of overcoming the limitations of positive science by finding the first principle of being? Philosophy does not here begin by conceiving nature , but instead by confronting a privileged given that is accessed immediately through some kind of intuitive contemplative grasp, from which everything else is to be derived.

What kind of a nature will it be that emerges within this enterprise? Is it going to be a nature that is structured in terms of a hierarchy of form? Will the philosophy of nature begin with some highest form from which one then derives other genera and other species and so forth, where the highest genera is that privileged given, that most universal natural determination on the basis of which everything else in nature owes its intelligibility and its being? In other words, will the nature that follows from ontology begin with a first principle of nature in which a hierarchy of natural forms is rooted? This would seem to be the itinerary most in keeping with the philosophical project that begins with ontology. Certainly, the example of Aristotle suggests that the quest for first principles has just this implication for how nature is to be conceived.

Something very different is in store for thinking nature when ontology gives way to epistemology as first philosophy. Once philosophical reflection questions the intuition of first principles of being and demands that knowing be investigated before accepting claims about its objects, the consideration of nature proceeds on a radically new footing. This new terrain is that trail-blazed by Kant in making the so-called transcendental turn. Abandoning ontology as first philosophy, one here turns to examine knowing to establish whether it is able to get at what is, so as to determine what knowing can authoritatively establish about objects of knowledge.

Making the investigation of knowing, epistemology, the proper starting point of philosophy might seem to be hopeless from the outset. After all, how could one possibly certify the truth of our cognition if one cannot compare our knowledge claims with their objects, since direct access to the given is precisely what is suspect? How then could any turn to investigate knowing shed light on whether the claims of knowing have any objective truth? It seems that one would have to have immediate access to being to see whether one's knowledge claims correspond to "what is", to "the given". That appeal to the given, however, is precisely what cannot be done with any authority, which is why one's cognition must first be certified through a prior investigation of knowing.

There is just one way in which the turn to investigate knowing could possibly have any bearing on the truth and objectivity of knowing. That is if and only if the structure of knowing determines the object of knowing. Only if what is known is determined by knowing can the investigation of knowing shed light on knowing's own objective truth. For if objectivity is determined by the structure of knowing, then a prior investigation of knowing, which does not appeal to anything independently given, can still bear upon whether knowing corresponds to its object. Of course, if knowable objectivity must be determined by knowing, objectivity turns out to be, at least in part, a construct of knowing. With epistemology serving as first philosophy, knowing can only know with any necessity and universality what it unfailingly puts into its object, what it automatically determines in its object.

This inversion of the relation of knowing to its object, whereby the object must conform to knowing rather than knowing conform to something independently given, has significant consequences that bear upon how nature can be thought.

First of all, objectivity in general is rendered something relative to cognition and thereby relative to subjectivity. One might qualify this relativity by noting that cognition is here characterized such that it is not merely subjective. One is turning to investigate knowing as it applies to "all of us" who share in consciousness in general or language per se or in a particular language. Accordingly, objectivity can be said to be relative not to subjectivity but to "inter-subjectivity".

Nonetheless, whether objectivity is relative to subjectivity or intersubjectivity, it retains a specific conditioned character that has fundamental ramifications for any attempt to know nature

. So long as objectivity is determined by the structure of knowing, no matter how cognition is characterized, objectivity as a whole is dependent, determined by something other than itself. Instead of being self-determined, objectivity is other-determined, governed by a necessity that is external to it. Insofar as objectivity is determined by the structure of knowing, objectivity as such becomes a domain of external necessitation, a domain in which autonomy is absent in principle.

Secondly, because all objects are determined in their know-ability by the same underlying structure of knowing, the latter's external determination of objectivity applies to all objects no matter what they are. Therefore this external determination is a necessitation that applies to all objects equally. A necessitation that applies to things all equally, irrespective of what they are, is an external determination that takes the form of law. In other words, the objectivity that can be known insofar as knowing determines its objects is a nature in the specific sense of a law governed domain of objects, all of which are equal before a law that is indifferent to what distinguishes them from one another.

Since knowable objects are here determined by a law that applies to them equally, certain types of necessary determinations are excluded. There cannot be any formal necessity, where objects are determined necessarily in virtue of what kind of a thing they are. Rather, "kinds" or "specific natures" or "forms" have no knowable necessary bearing upon the objective reality of things. The only kinds that natural things can be known to have are empirically given family resemblances, whose boundaries are contingent upon particular observations and therefore inherently corrigible. New examples may always be encountered that call for revising the identity of a species , whose limits remain ultimately provisional and arbitrary. Consequently, there can be no kinds of natural things that are known to be necessary.

Similarly, no import or end can possibly have any necessary hold upon objects because the import of an object is not something indifferent to what it is. Form and function go together. If the only necessitation that is objective is one that applies to objects no matter what they are, then there can be no teleological necessity. This is true whether the end in question is external to the object, as with an artifact , or internal to the object as with a living organism . In either case, the end stands apart from what law mandates for all objects that fall under its sway.

Consequently, the only necessitation that can apply to a nature that is a law-governed objectivity is a material causality, a causality that applies to objects solely with respect to their undifferentiated matter, with indifference to their form and import. This causality can be called "efficient causality" in distinction from formal and teleological causality, but in the universe of foundational epistemology , it is the one and only necessity, comprising objective causality per se.

Here, then, necessitation is the rule of the law of material or efficient causality, a determination of things indifferent to what they are. Objects are all subject to a law that applies to them as mere matter, with everything else falling out of the equation when it comes to what can be known in any necessary universal way. Objectivity in effect becomes a reality governed by laws of matter, exclusively limited to the workings of efficient causality. The critical philosophy that supplants ontology with epistemology as first philosophy thus ends up rendering nature a domain of mechanism . To the extent that mechanism has a material necessity that, as such, cannot be established by observation, it calls for a rational conception of nature as a mechanism and for the philosophy of nature to take the form of a pure mechanics , pure in the sense of relying upon reason alone.

As much as this transformation in conception has come to dominate modern philosophy, certain problems immediately crop up with its adoption. To begin with, if nature is reduced to a

domain of external necessity comprising a mechanism of material lawfulness, there is no room for the self-moving reality of life or the self-determination of any form of rational autonomy. Construed as a mechanism , the universe has no place for independently thinking and acting agents. Empirical scientists and living philosophers find themselves banned from the world of their theories.

For the transcendental philosopher, this has the fateful ramification that the object-determining conditions of knowing can never fit the parameters of objectivity and be objectively known. Kant himself is in no position to make any claims whatsoever about consciousness in general because the mechanism of nature precludes the worldly presence of and access to other consciousnesses. Indeed, since the lawful determinism of nature also precludes consciousness being present to itself, self-consciousness becomes impossible. Further, the reduction of objectivity to a conditioned mechanism means that individuals cannot interact with one another as agents and engage in moral community, let alone engage in empirical investigations and communicate with others.

This self-defeating outcome is indicative of a challenge that must be addressed by any philosophizing about nature . Philosophical theory is in trouble if it conceives nature such that there is no way in which living intelligence can make its appearance in the world. If nature has no room for the reality of philosophy, let alone for the reality of natural science, there can be no theoretical knowledge of nature , unless the knower of nature is a transcendent, non-worldly being. To the extent that scientists and philosophers are worldly individuals, their theories cannot be supportable unless they determine nature so that it can accommodate the presence of the individuals who have the free intelligence to theorize critically about their universe.

This proviso comes most directly to the fore in the philosophy of mind , which must account for the psychological conditions of its own exercise, but it cannot be ignored by the philosophy of nature . One must wonder how it can possibly make sense to construe the universe such that it is impossible for thinking about nature to occur within the natural world.

Nonetheless, many have looked upon this second fundamental form of philosophizing as being the final word, with no other alternative to its foundational epistemology than retreating to the pre-critical dogmatism of ontologists or accepting an uncritical positive science that unquestionably kowtows to the primacy of empirical data. There is, however, another option that has not been accepted into the canon that reigns in most recesses of the academy. This option consists in the attempt to do philosophy in recognition of how foundational epistemology is plagued by the same dogmatism that it exposes in its repudiation of ontology as first philosophy. Although it is certainly dogmatic to undertake ontology as first philosophy and immediately read off the character of the given, it is just as dogmatic to turn directly to cognition and make claims about knowing in place of the given. The “transcendental” philosophy that regards itself as critical by refraining from making direct claims about what is actually proceeds equally uncritically as the fundamental ontologist it critiques by turning away from “being” to make direct claims about knowing. The critical philosophy never criticizes its knowing of knowing, which is distinct from the knowing it investigates because that knowing is not a knowing of knowing but a knowing of objects different from itself. From the very outset, there accordingly is something fundamentally uncritical about the transcendental turn, leaving the conception of nature it entails tainted by dogmatism.

The failures of ontology and foundational epistemology leave us with the challenge of undertaking a different philosophical strategy, initially defined in the negative terms of what must be avoided. This strategy foregoes making any claims directly about “what is” or directly

about knowing, without forfeiting the field to positive science, which begins with preconceptions about what is and about what method to employ. Refraining from presupposing anything about the given or about knowing, this strategy undertakes to begin philosophy with no privileged subject matter or method, but instead to start with nothing determinate at all. If such presuppositionless philosophy ends up coming up with something determinate, it will have to be something that is generated through this very engagement in operating without any dependency on any assumed procedures or givens. It will have to involve a radically autonomous development that gives rise to both its topics and their ordering. This is the project of a systematic philosophy without foundations and within it nature will have a very different character from what it has as an object of dogmatic or critical philosophy. No longer will nature have to be conceived as a domain structured by underlying first principles or as a mechanism governed by material law. What nature will now comprise, however, is far from clear.

To understand how nature ought to be conceived without having to reinvent the wheel, it is important to look at the achievements of the most prominent pioneers of these three fundamental options in philosophical investigation, each of whom has not been afraid to obtain knowledge of nature through the autonomous employment of reason. Whereas the strategy of doing ontology as first philosophy has its greatest pioneer in Aristotle , the critical philosophy substituting foundational epistemology for ontology has its groundbreaking innovator in Kant, and systematic philosophy without foundations has its great initiator in Hegel. All of these thinkers have made an attempt to think nature , but all three go about their theorizing differently and end up characterizing nature in diverse ways.

Aristotle and Kant each conceive nature in general in terms that appear to apply only to a particular natural sphere. Aristotle categorizes nature in a way that seems most appropriate to conceiving living things. By contrast, Kant reduces nature , as it can be known philosophically, to a domain of mechanics, bringing to consummation what is foreshadowed in the similar efforts of early modern philosophy, where what is “clearly and distinctly” knowable in nature are the “primary properties” that pertain to the spatiotemporal determinations of material bodies. Kant’s approach may suit the most abstract and elementary domain of nature , which involves the purely material being of the universe, as a realm of matter and motion without further qualification. Nonetheless, as much as Aristotle and Kant may provide conceptions that apply to certain *particular* natural spheres, they absolutize these privileged dimensions to the exclusion of any others.

Hegel, for his part, presents a more encompassing philosophy of nature that incorporates something akin to Aristotle ’s conception in addressing organic nature , as well as something akin to Kant’s pure mechanics in addressing the most rudimentary dimensions of inorganic nature . Hegel, however, does not limit the conception of nature to these two domains. Instead, he also conceives further aspects of nature under the heading of physics, chemistry, geology, and meteorology. These go beyond mechanics to comprise other kinds of physical reality where matter gets further differentiated and involves processes that are not reducible to the mechanism of matter and motion, but do not yet take on the character of life.

In thinking through the contributions of Aristotle , Kant, and Hegel to the conception of nature , it is important to recognize how the way they respectively characterize nature is wedded to their distinctive approaches. More important, however, is to examine the provided determinations of nature in their own right and to see to what degree they can be made use of in trying to think systematically about nature as a whole. Our task is accordingly to attempt step by step to conceive the totality of nature by drawing upon the achievements of these foremost

representatives of the three fundamental forms of philosophizing. No matter what philosophical topic one is addressing, it is always prudent to examine what Aristotle , Kant, and Hegel have had to offer, since otherwise one risks squandering one's life repeating what has already been achieved. In the case of the natural universe, it makes sense to draw upon Hegel's philosophy of nature as our encompassing framework, since his conception contains the distinct categories and types of subject matter that Aristotle and Kant exclusively privilege, as well as supplementary concepts and topics that prove hard to ignore. Admittedly, Kant and Aristotle think about nature with very different ranges. Kant expressly restricts the philosophically knowable nature to the domain of pure mechanics . Aristotle , like Hegel, is unafraid to think about nature in its complete totality. Unlike, Hegel, however, Aristotle will think about the entire universe with the particular categories that most appropriately apply only within the particular natural domain of life.

Accordingly, we will not hesitate to stand upon the broad shoulders of these three great pioneers in philosophy, but we will do so in a systematic manner. We are going to begin with those dimensions of nature that have to be dealt with first because all further aspects of nature incorporate or depend upon them. By following out such a development of internal constitution, our examination of nature will have a non-arbitrary character because what will determine the order of the treatment will be the content of the subject matter. Our first task will therefore be a matter of identifying those determinations of nature that come first in thought as well as reality to the extent that all other dimensions follow and depend upon them structurally. By operating in this way, we will see to what degree reason can provide insight into the full field of nature .

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2. The Presuppositions of Ancient and Modern Conceptions of Nature

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Before turning to the systematic starting point of the philosophy of nature and seeing what light Aristotle , Kant, and Hegel shed upon its character, it is worth putting in perspective the fundamental differences between ancient and modern conceptions of nature . Michael B. Foster's [1] seminal essay, "Christian Theology and Modern Science of Nature ", [2] is a key resource for understanding how modern science and modern philosophy of nature contrast with ancient thought. Thinking through Foster's argument provides us with basic divergencies that will play a crucial role in conceiving the different spheres of nature .

2.1 Theology, Philosophy, and the Presuppositions of Natural Science

Contrary to all those who oppose Christian theology and modern science, Foster's two part essay, "Christian Theology and Modern Science of Nature ", aims to show that Christianity provides the theological preconditions for the philosophy of nature that underlies modern science. Foster begins by pointing out something that is important and obvious, yet completely ignored by the practitioners of the philosophy of science. Namely, every science of nature depends upon presuppositions about nature that cannot be established by the methods of the science. Our inductive natural sciences, which rely upon observation, presuppose something they can never validate. To understand what they presuppose, one must remember that empirical natural science does not just observe nature . If natural science just did that, animals would be natural scientists. Natural scientists, unlike the most perceptive brutes, *think* about nature on the basis of their observations. Further, for reasons that will become clear as we think through Foster's essay, natural scientists think about their observations in search of laws of nature that apply to all things, no matter what they are. In so doing, they seek explanations in terms of efficient causality. On all these accounts, natural scientists presuppose that nature has a uniformity that is indifferent to the specific essence of natural things, a uniformity that is susceptible of being subject to laws of efficient causality.

Such uniformity cannot be established through natural science's own methods of induction, whose reliance upon particular observations can never independently verify the necessity and universality of any perceived connections.

To come up with laws based upon observations, one must presuppose the uniformity of nature with regard to space and time . What one observes repeatedly in one's sphere of observation can offer support to some universal law only if the recurring relation applies at all times before and after as well as everywhere else. Observation cannot remove that presupposition simply because no one nor everyone can observe everywhere and at all times.

Further, as Foster notes, [3] if one wants to pursue science as Descartes does, for whom nature is to be investigated using geometric and more general mathematical methods, one must presuppose something else that can never be established mathematically. The assumption of the mere uniformity of space and time may provide some commensurable measure, so necessary for mathematization. To be susceptible of mathematical determination, however, what is in space and time must have a homogeneous materiality. Natural things, to the extent that they can be truly known as objects of mathematization, must be devoid of any essential qualitative character, whose incommensurability resists quantification. Qualitative difference may be acknowledged as confused and indistinct "secondary" qualities that mark the *appearance* of nature , but the true objectivity of nature must comprise a commensurable bodily nature . No mathematical investigation of nature , however, can establish that this is so, for quantitative analysis of the world takes it for granted.

In face of this inability of natural science to establish the homogeneous materiality and the uniformity of space and time that it presupposes, one could simply take a leap of faith, as many natural scientists and non-scientists do. Or one can appeal to reason and rely upon the philosophy of nature . It might well be that the philosophy of nature can do nothing more than determine that nature has a material homogeneity that allows for mathematization, as well as a spatial and

temporal uniformity allowing for the establishment of laws. The philosophy of nature might have nothing more to offer than that, leaving all other knowledge of nature to empirical science. Even if that were the case, it still reflects how natural science operates with assumptions that it cannot legitimate on its own and that, if they are to be legitimated rationally, a philosophy of nature is required.

Foster makes an additional claim that appears less than self-evident and, to say the least, more controversial than the invocation of the philosophy of nature as the ground for natural science. He maintains that just as natural science depends upon the philosophy of nature to account for its fundamental presuppositions, so the philosophy of nature is dependent in its turn upon theology. [4] Broadly speaking, theology is the doctrine of God . Foster points out that there can be no doctrine of God that does not at the same time either contain or imply a doctrine of the world. [5] For example, in Christian theology God is a creator and the world is a creation. By contrast, Brahmin theology has God in one of his forms producing the world by an act of generation . The world is then an offspring with a specific character very different from that of a creation. In Plato 's *Timaeus* God is not a creator or parent of nature but an artisan who imposes form upon material chaos to produce the world, just as a potter creates neither the material nor the design of a pot, but imposes a given form upon clay to make that artifact . For Aristotle , God lives apart from the world and directs his activity not upon nature but exclusively upon himself. God is self-thinking thought and God influences nature as an unmoved mover who operates as a final cause. Celestial bodies are drawn to God by a kind of love. Unlike the Aristotelian Divine, the Gods of ancient Greek mythology are not really apart from the world, but are in it and have the same nature as the world. This identity has its consummation in pantheism, for which God is identical to the world.

As these cases indicate, affirming a certain conception of the divine at the same time affirms a certain conception of the world. In particular, whether God is in or out of nature is of capital importance in how one views nature .

One might object that Foster's claim that the philosophy of nature is based on theology ignores those theories, such as those of Kant and Hegel, which conceive nature without obvious reliance upon an antecedent doctrine of God . Foster, however, points out that conceiving nature without dependence upon God cannot escape theology. Atheism is the denial that there is anything except for nature and this implies that nature is self-contained and can be explained only in terms of itself. Accordingly, if one is to look for the sufficient cause of any natural happening, one must look to the natural world itself. As Foster notes, it is difficult to see how such an atheism can really be distinguished from pantheism. Pantheism is the notion that God is the world. What does it mean for God to be the world? Nature , as identical to God , is nothing other than a self sufficient totality not determined by anything else, the one and only substance, as Spinoza would say. Is that doctrine of God really any different than atheism? [6]

Whether or not the philosophy of nature depends upon theology, different conceptions of God can be seen to carry with them different conceptions of nature . This connection is fruitfully explored by Foster in showing how ancient and modern philosophies of nature fit together with very different theologies. Foster is concerned above all with laying out the connections between Christian theology and the philosophy of nature presupposed by modern natural science. What he uncovers sheds important light on the distinguishing features of ancient and modern philosophies of nature , which has important implications for conceiving the particular spheres of nature that ancient and modern theories best grasp.

In considering the relation between Christian theology and modern natural science one can

hardly ignore that both derive much from ancient thought, which provides in the first place the very idea that nature can be the proper object of science. As far as the Western tradition goes, ancient Greek philosophy first establishes the idea that God can be the object of philosophical understanding, as well as the very idea of science itself. Nonetheless, there are defining elements of Christian theology that derive not from ancient Greece but from revelations in the Old and New Testaments. This involves radically distinct features that are incompatible with ancient thought. As Foster shows, the development of Christian theology largely involves a progressive assimilation of these elements and an ongoing struggle to determine to what degree they can be reconciled with the heritage of ancient Greek civilization. [7]

The same predicament applies to modern science . In important respects, modern science draws upon ancient science, but also fundamentally differs from it. As Foster shows, the differences in the methods of modern and ancient science are rooted in distinctly different philosophies of nature , corresponding to the differences between ancient and Christian theologies.

Let us follow Foster’s account, so as to focus our bearings for systematically conceiving the different spheres of nature .

2.2 Ancient Theology and Ancient Science of Nature

Two elements in Greek theology are fundamentally incompatible with the revealed doctrines of Christianity. The first is the element of paganism and the other is a certain kind of rationalism. [8] Paganism can be understood simply as a failure to distinguish God from nature . This failure can take various forms. It does not have to involve polytheism where the Gods in their plurality are in the world themselves. Rather this failure is found wherever there is lacking the idea that God is a being separate from the world, that God is spirit, devoid of any natural character. A God that is spirit may still operate in the world, but it can only do so in a non-natural way using will and reason.

To deny paganism and conceive God as non-natural has obvious repercussions for the nature of the world. First of all, nature cannot be divine. Nature cannot share whatever it is that makes the divine what it is. Instead, there will be something fundamentally different about these two domains.

Such difference is lacking in the pagan element exhibited in Plato ’s *Timaeus*, which foreshadows the paganism pervading Aristotle ’s *Physics*. Admittedly, the pagan failure to distinguish the divine and nature might seem absent in the notion of God that Plato presents in the *Timaeus*, where a divine demiurge structures the world in a way that might appear to sever any connection between the divine and the world. After all, the divine demiurge, who produces the world as an artifact , does not directly share in the nature of its product. An artifact is the product of a craft activity where an artisan antecedently conceives a form that the artisan then imposes upon a given material. The resulting product is a composite owing its character to both the form it embodies and the material that takes on that design. The activity imposing form upon the material does not reside in the product. Rather, the formative activity comes to an end with the emergence of the product. The artisan exercises two capacities. The artisan conceives the form in distinction and prior to its embodiment as well as engages in the formative activity of imposing it upon the material. None of these capacities are shared by the product. The artifact possesses its form in a way that is not itself imbued with any kind of agency. The form of an artifact is not self-realizing in any respect. It is something imposed by an external agency upon the material.

These differences between artisan and artifact might seem to eliminate the element of paganism from the conception of nature in the *Timeaus*. There is, however, another aspect in Plato ’s account, according to which the divine demiurge is characterized as being related to the world as father to son. On this account, the relationship between divine and nature is one not of manufacture but of generation , which involves inextricably pagan elements. [9]

This is because, first of all, parent and offspring share the same form, being of the same kind. Secondly, the form they share is different from that of an artifact because of how the offspring is generated. The form does have an antecedent existence, like that of an artifact . Nonetheless, whereas the form of an artifact exists antecedently in the mind of the artisan, the form of the offspring is already embodied in the parent. The process of generation does not depend upon the parent antecedently conceiving the form the offspring will share. The parent does not generate the child by preconceiving its design and imposing it upon some given material. Rather, the form in question is an active form animating the parent. It is a soul, whose life process the parent has and imparts to the offspring. Accordingly, if the divine relates to the world in terms of generation , the divide between God and nature is removed. Both are intimately conjoined.

As Foster notes, the presence of this account of the divine demiurge in the *Timaeus* indicates Plato ’s failure to distinguish two fundamental processes, making and generation , which are really not compatible with one another. [10] An analogous failure to distinguish making and creation is found in the ancient Greek tendency to conflate the art of artisanship with fine art. Unlike an artifact produced by craft, fine art is something created. The genuine object of fine art does not embody an antecedently given form because if it does it does not deserve respect as a creative expression, being more of a formulaic production, lacking the novel individuality that only creation can impart.

Not surprisingly, when Christian theologians make use of Plato to provide a philosophical justification of Christian dogma, they find different aspects of Plato ’s doctrine more suitable than others. As Foster observes, the notion of the divine as a demiurge is more employable than the notion of the divine as father, although both notions do appear in Christian doctrine. [11] The doctrine of the Trinity invokes generation in the birth of the son of God , whereas the doctrine of creation can invite some comparison with the notion of manufacture. Nonetheless, there are fundamental differences in how Plato employs generation and manufacture and how the latter could apply to the Trinity and creation. Whereas Plato applies generation and manufacture to the same object, nature as a whole, Christian doctrine applies generation to the birth of the son of God and creation to the world.

It is useful to keep track of these distinctions, which will prove crucial in thinking about different kinds of entities and what categories are applicable to different domains of nature , as well as to nature as a whole.

Although both generation and manufacture (*techne*) terminate in an information or organization of a given matter, this occurs in very different ways. [12] In the case of manufacture the active information is completed when the product is produced, which terminates the formative process. In the case of the generation of offspring, the answer is more complicated. Is the ordering of generation completed with inception or birth or when the offspring is full grown? Unlike an artifact , an offspring is self-organizing insofar as it matures and maintains itself through its own life process.

Similarly, the form that is embodied in manufacture and generation has a form antecedent to the “informing” process. In the case of manufacture, the form is present in the mind of the artificer. In the case of generation , the form is inherited from the parent, who possesses it as the very principle of life that is at work in the parent.

Moreover, in both an artifact and an offspring, the form that is embodied plays a dual role. In each it figures as both the essence and the species of the emergent factor. The form operates as the essence in that it is that which makes that product what it is. Whether the entity be a manufactured chair or a generated human being, the form that gives it its identity is antecedently realized, albeit in different ways.

On the other hand, the essence that determines what the product is is bound up with its species being. Thinking about entities in terms of genus and species distinctions is an approach privileged by both Plato and Aristotle . To what extent is this categorization appropriate for entities construed as artifacts or as offspring? The category of species has obvious application to offspring insofar as an offspring comprises a reproduction of the essence of the parent, thereby upholding the species to which they commonly belong by becoming a new member of the species .

Can the same be said of an artifact ? The nature of the production of an artifact ensures that the form is separately conceivable from its particular embodiment. Therefore this form or design

can be embodied in multiple products, each of which is of the same kind, as defined by the form they share. The form in no way establishes the individuality of the artifact , since it does not determine what distinguishes any product from other exemplars of the same form. All it establishes is that the artifact is one of a kind which has other potential or actual exemplars.

Nonetheless, it bears repeating that there are decisive differences in how production and generation operate and how form figures within each. The artificer possesses the form by conceiving it, not by embodying it. By contrast, the parent possesses the form that is imparted to the offspring by embodying it, by being a realization of it. The artificer is not a chair but makes a chair, but the father is of the same species , the same kind of living entity as the offspring. Precisely because the artificer does not embody the form to be realized in the product, the form must be antecedently conceived to guide the manufacture. Alternately, since the form is embodied by the parent, it does not have to be conceived for generation to occur, which is why there can be generation in organisms that lack any power of conception.

Furthermore, the form functions very differently in artifact and offspring. In the case of the offspring, the form is the cause of its spontaneous motion, as well as of its growth and of its very existence. The offspring is a living thing whose life process enables it to engage metabolically with its environment, grow, and reproduce. The form of the organism has the power to preserve the organism and resist its disintegration and destruction by external factors. None of this is present in the artifact . The artifact is completely dependent upon the artificer for the activity that embodies in it its form and sets it in any functioning in which it may become subsequently engaged. The activity of its production comes to an end with the manufacture of the product. The product does not contain or share in that process of manufacture. Nor does it repair or actively preserve itself. The offspring, on the other hand, functions as if it contains within itself its own artificer. It incorporates the power of the producer, as if somehow the craftsman could include his own agency in the product. The living organism that issues from generation has a spontaneous movement of its own, by which it is determined from within itself.

Admittedly, an animal can be caused to move by an impulse communicated from without. Such an external stimulus is, however, very far from being able to determine completely either the nature or the quantity of motion that follows. If an ocean wave surges into an iguana, how the iguana moves is very different from how a piece of drift wood is tossed about by the water. An inanimate object does not move itself in function of its species being, but rather has motion imparted to it in function of the force communicated to it, its own mass , and anything about its shape and texture that affects the friction produced by its movement. All that matters is the inanimate object’s shape and mass . Shape is different from the form that determines the essence and species being of a living entity. A dead iguana has the same shape as a living iguana but if you kick the dead iguana the force imparted to it will have a different result than if the same kick is aimed at a live iguana. The motion that the living organism undergoes will depend upon its own nature , which largely determines how it reacts. Its nature or form is not something merely material, whereas shape has to do solely with a thing’s material configuration. The form or nature pertains to the organism ’s kind and its kind is not reducible to any sensuous property. It is something of a different sort. This is why the nature of the offspring bears upon how it moves and what results when an external force is imparted to it.

By contrast, the form of an artifact , imparted to it by the activity of the artisan, has no bearing upon what happens when motion is communicated to it. That the artifact is a chair does not add anything to what will happen to the chair when an external force acts upon it. What counts is the chair’s shape , mass , and texture (if friction is involved).

As Foster points out, there are occasions when the nature of the offspring has no bearing upon what happens to it when force is imparted to it. [13] This is the case when the force is of such a magnitude that it completely overpowers the nature of the organism , leaving it acted upon as though it were dead natural material or an artifact . A tsunami may be powerful enough to sweep along a living iguana with the same speed and trajectory as any equivalently sized and weighted material.

In distinguishing between artifact and offspring, it is important to keep in mind that both are distinct from what is inanimate and not a product of manufacture. The latter has solely material features, which may be further qualified, as we shall see, as physical and chemical.

Although the artifact has no source of movement of its own, the form of the artifact is no more just shape than the form of a living thing. Unlike shape , the form of the artifact is something intelligible that can be represented apart from its sensuous embodiment. That sensuous embodiment does have a sensible configuration as well as a sensible mass which bears upon what motion is imparted to it because an artifact does not impart motion to itself.

Moreover, the form of the artifact involves no kind of conatus, no urge to preserve itself, no process that resists disintegration. [14] If a pot does not fall apart, this depends upon its spatial configuration and the material of which it is composed. These factors are different from the form of being a pot. The pot's function, however, depends on that form.

One way of grasping the distinctions here intimated between a form as it is present in an artifact and a form as its present in an offspring is to regard the form in what is artificial as being an embodied concept. The form of the artifact is an embodied concept insofar as it is something conceivable and must be antecedently conceived in order for it to be produced. By contrast, one can view the form of a product of generation not as an embodied concept but as an embodied soul. These two construals of form provide for two different ways of thinking about nature , in light of two different ways of regarding the divine. One considers the divine to produce nature as an artificer, as a demiurge who imposes form upon material, giving order to chaos. The other considers God to generate nature as an offspring. If God is the artificer of nature then nature lacks all participation in the power by which it was produced. If God is the parent of nature , nature must exhibit the divine nature ; it must possess within itself the same spring to activity as is in the divine.

Foster suggests that regarding nature as being generated from the divine involves a theological conception that fits the Aristotelian philosophy of nature , whereas the theological notion of divine as a demiurge or artificer of nature fits the philosophy of nature presupposed by modern science . [15] Indeed, the distinction between the nature of an offspring of generation and a product of manufacture is identical to the distinction Aristotle employs when he is differentiating a natural from an artificial object.

Following Aristotle , one can distinguish animals from artifacts precisely insofar as how the form of one is and the form of the other is not an efficient cause of movement. Take the case of the iguana. If you want to know how an iguana will move if struck by a given force you have to know something about the nature of the iguana. If you want to know how a thimble will move if struck by a similar impact all you need to know are its material dimensions, its mass and figure. Its form as a thimble, its function as a thimble, is beside the point.

Insofar as Aristotle conceives natural objects in general in the terms that apply to an animal and not an artifact , the motion that is proper to a natural object will be determined by its form or specific nature . This will apply both with regard to how the natural object moves itself as well as to how it resists force applied to it. So, on these terms, you only have to know the nature of fire

to know that it is going to move naturally upwards or that if wind be blowing against it, it is going to resist it in a certain direction because of what it is. By contrast, if you know something to have the nature of earth, you know that it moves downwards and not upwards like fire. Or if you know the nature of a celestial object, you know that it will engage in a kind of circular motion that will not be true of terrestrial objects. By thus thinking of natural objects as offspring of generation and as thereby having an active form akin to a soul, we give natural science the task of uncovering the specific natures of things. That becomes the focal point if one wants to understand nature , having construed it as the product of generation .

By contrast, the modern science of mechanics is going to explicitly ignore the nature of a thing in order to understand its motion. The laws of motion are going to be seen to be the same for all material objects. It does not matter whether one drops a book, a feather, or a cannon ball, from the leaning tower of Pisa. So long as one takes into account how its shape determines the resistance of air to its fall , the laws of motion will apply to an object irrespective of what it is. Scientific understanding will here only be possible on the assumption that the quantity of motion of a natural object is precisely commensurate with the force communicated to it and has nothing to do with its specific nature . If you think the specific nature has something to do with it, then you are losing all touch with scientific reality and succumbing to Aristotelian fantasies.

2.3 Nature as Product of Making Versus Nature as Product of Generation

Can conceiving nature as a product of generation confer sufficient intelligibility upon the objects of nature for their scientific investigation? This question is relevant not only for the viability of any Aristotelian theory of nature , which fits a theological notion of the world as generated from the divine. It also is relevant for any investigation of that part of nature , namely, organic nature , whose objects seem to be and be thinkable as offspring.

It is quite obvious that when we deal with artifacts, their form or essence is inherently intelligible. The artifact is the embodiment of a concept that must be antecedently conceived by the artificer in order to produce the artifact .

As Foster points out, the intelligibility of an artifact is not comparable with the intelligibility of what Locke identifies as an abstract general idea. [16] For Locke concepts or universals are ultimately abstract general ideas, literally abstracted from sensuous ideas that are found in experience to be common to a plurality of sensuous objects. [17] Abstracted general ideas are just common sensible marks. Although their content is found in a plurality of instances, it remains something that is not conceivable. Rather, the content of the general idea can only be sensed and then re-presented by imagination, whereby what is abstracted from one sensation can be placed next to other abstracted marks so as to construct the general representation of the abstract idea. This general representation is not equivalent to the form that an artifact has. The form embodied in an artifact is not something that can be encountered in all the sensible perceptions of things that have that form. Indeed, it cannot be found in any of those sensible impressions. The form is intelligible and definable. It provides the answer to “what is” the object it informs, whereas no image or any duplicated element of an image can serve to define something. Sensible contents, no matter how abstracted they may be, are not sufficiently universal to serve the purpose of definition. One cannot use one’s own picture to characterize what it is to be human. Nor can any sensible feature we share in common be definitive and essential to what we are.

The same limitation applies to using sensible contents to grasp a function. An archeologist, who is concerned with comprehending artifacts recognizes that one can only understand what an artifact is by *thinking* its function. An artifact ’s defining function cannot be determined by simply measuring its shape or perceiving its color , texture, or any other of its sensuous qualities. None of these sensible contents will give you its form and function, for the latter are inherently intelligible, conceivable, and definable. As definable, form and function are subject to all the methodological operations that proceed from definition. Insofar as definition determines the genus and species of an entity, the intelligibility of an artifact allows for the various kinds of judgments and syllogisms that species being involves and upon which Aristotelian science feasts. [18] With the apprehension of species , differentia can be necessarily derived.

The situation is entirely different when one operates with abstracted general ideas. These empirical representations offer at best demarcations of class based on family resemblances that can always be undercut by further observations. If one draws inferences about an individual in virtue of its class membership, one is operating in circles, since the boundaries of the class are predicated upon the given features of its members. The commonality of family resemblance is based upon all the individuals that are part of it because the class or “family” has no existence apart from those individuals that are observed to resemble one another.

Aristotelian science presumes to operate with the deductive authority of a science of form and function, but it is not really concerned with artifacts or with forms that have the passivity of designs imposed by art. Rather, Aristotelian natural science is concerned with forms that have efficacy. Although such science relies upon definitions, judgments, and syllogisms that presume the intelligibility of an embodied concept or *logos*, it addresses natural things that have a form which is not of a *logos* but of a *physis*, an efficacious self-moving, self-realizing form. [19] Knowledge of such form can provide the key to understanding nature because it determines not just what something is but also how it moves and what end it has. All of these considerations go together precisely insofar as we are dealing with an ensouled entity whose form is self-moving and self-realizing.

Does Aristotelian science fall into an insoluble dilemma by using procedures that depend upon a kind of intelligibility possessed by artifacts to understand natural things whose form is of an entirely different character? Although Aristotle does distinguish artifacts from natural things, at many conjunctures he tends to conflate the two and in conflating the two, attempts to understand nature by appealing to aspects of manufacture. This engenders the same kind of confusion we find in Plato 's *Timaeus*, where natural entities are conceived on the one hand as products of artifice or *techne* and on the other hand as arising from love and generation .

Foster identifies the underlying challenge, writing that "the possibility of an Aristotelian science of nature thus depends upon the two-fold principle that the form of a natural object is at once superior in respect of efficacy and not inferior in respect to intelligibility to that of an artifact ." [20] In other words, what is natural is natural insofar as it has an efficacy of its own that allows us to understand how it functions in terms of its nature . If instead we just have artifacts, there could be no scientific understanding of the world because what happens would have no connection to what things intrinsically are. Events would be completely accidental to their nature and that would leave natural processes with no intelligibility. On the other hand, if matter is without form, it would be indeterminate and inscrutable. If, however, the science of nature depends upon things having a form with an efficacy superior to the embodied concept of an artifact , they still must retain sufficient intelligibility for scientific comprehension. How can nature then allow for any rational demonstrations?

Foster maintains that if Aristotle had properly taken note of the distinction between artifacts and natural things, he would have recognized that the efficacy that form possesses in nature is something it has at the cost of the intelligibility that artifacts possess. [21] The intelligibility of the artifact depends upon the manner of its production. It is a condition of the artificer's activity of manufacture that before the artificer begins work the artificer has to conceive the form that is going to be embodied. The artificer must consciously distinguish the end that his activity is aiming to realize from the means of its realization. The means that *techne* employs to realize the end are the materials as well as whatever tools are employed in the process of embodying the form. These are all distinguished from the form being embodied, which must be consciously apprehended apart from them. The genuine artificer has to be able to say what is being made, not by assigning a name to some individual occurrence in a nominal way, but by identifying the form that is not sensuously but only verbally manifest. The same *logos* that can be presented in the words of the definition is the essence of the artifact , the end in distinction from the means, the form in distinction from the matter.

By contrast, the natural object that comes into being by generation has communicated to it the efficacious ensouled form of the parent. [22] This efficacious form is communicated without any conceptual grasp. Indeed, one might ask whether there is a concept to be grasped or whether

the nature of the form has a non-discursive character. Although the form has to be antecedently present, it is present not in the form of a concept that is known, not in the form of *logos*, but as possessed in the form of a nature , in the form of *physis*. In this respect, it is not something distinguishable by reason from the generator or from the matter of its embodiment.

Foster suggests that Aristotle makes natural entities more intelligible than they should be by maintaining an analogy to artifacts. [23] Artifacts are intelligible because they embody a concept that can be clearly distinguished from their matter and the artificer has conscious knowledge of that form. With regard to a natural thing, the question is not just, "Is its nature something that is consciously apprehended?" Rather, the question is, "is its nature something that could be apprehended conceptually?" Can one really know the concept of a natural thing if it has an efficacious form and is generated? Is it definable like an artifact or like a mathematical object, which might be considered a type of artificial entity constructed in intuition? Or does the fact that the form in question has a self-realizing aspect give the natural entity a very different character that may not allow for the natural science that Aristotle invokes? Foster maintains that if Aristotle had recognized the difference between artifact and natural thing, he would have recognized that how natural objects are distinguished from artifacts makes them incapable of both definition and treatment by the scientific methods he employs. [24] Foster at this juncture does not say very much to support his claim. He simply points out how manufacture differs from generation by having a conceivable form that the latter does not employ. Does that difference, however, mandate that the nature of a natural thing cannot be conceived, that it cannot be defined, that it is something about which one cannot make any necessary judgments?

Like Aristotle , Foster will admit that when we are dealing with living things and animals in particular, what they are has necessary bearing upon what they do. That, however, does not mean that there is an a priori concept of an iguana or an a priori concept of a human being. There may be an a priori concept of a rational agent, but a homo sapien is a contingent being, who may instantiate rational agency, but hardly does so exclusively. Particular organisms may be contingent and, strictly speaking, indefinable, but can there be an a priori concept of what it is to be a living thing?

Foster points to a very familiar and important passage in Aristotle where Aristotle tries to make sense of what is efficaciously natural by appealing to notions of artifice, of manufacture. [25] Aristotle famously declares that a natural object is like a physician who treats himself, thereby being the cause of his own health. [26] Aristotle conceives of medicine as a craft, that is, as an art in the specific sense of technique , where the physician relates to patients in the way in which an artificer relates to materials. That is, the physician imposes form upon a given material, making the body accord with the harmonious design of health. Like any other artisan, the physician knows the form antecedently through his knowledge of medicine and imposes it upon the patient, who, in being so informed, regains health.

What is different here is that the self-curing physician is both agent and patient at once. The physician operates on his own body in light of the knowledge of the form that is to be imposed. The operation is directed upon the physician's own body but it is informed by this knowledge that is antecedently had and, in a sense, remains distinguishable from the means to which it is be applied. So here we have something that might seem to provide both dimensions of efficacy and intelligibility. Here the object of the activity contains the power of informing itself, of imposing form upon itself. The physician acts upon himself, imposes a form that is antecedently conceivable, but here the object that is being acted upon contains the power to inform itself at the same time that it exercises the capacity to antecedently conceive the form it is going to embody.

Efficacy and intelligibility thereby are combined and this might seem to remedy the situation. Through analogy to the self-curing physician, we can conceive of natural things as moving themselves and yet being intelligible in terms of the same kind of operations that allow for cognition using definition, judgments, and syllogism.

Clearly the self-curing physician is more than an artifact . The self-curing physician is an object that has taken on a form, but it equally wields the power to impose that form upon itself.

At the same time , the self-curing physician is not just a natural object on Aristotle ’s understanding of what it is to be by nature . The process by which the physician cures and preserves himself involves the mediation of medical knowledge, of knowing the form of health. Knowledge of the form is thus here a precondition for the production of health. In the natural object, however, the *physis* that is the active form preserves and sustains itself independently of any intervening knowledge. The organism maintains itself and reproduces without having to know its own form.

Moreover, the healthy individual does not involve the activity of a physician curing himself of disease. The condition of health is arrived at with the completion of the intervention of the doctor, even when it is a self-intervention. The process of health that has been reinstated by medical treatment now proceeds independently of any knowledge of or meddling by medical science. Consequently, Aristotle ’s example of the self-curing physician does not really work as an account of nature . The efficacious form of a natural thing realizes itself without any intervention of knowledge, without the articulation of that form as a separable concept that can be imposed upon the natural entity as if it were passive material awaiting the imposition of some design. There is something fundamentally incoherent about Aristotle ’s appeal to a reflexive craft. This incoherence is equally on display in such other notorious examples as where Aristotle claims that if a house could build itself it would be just like a living thing. [27] Once more, Aristotle presumes that one can make sense of the self-activity of the living thing as if it were an exercise of craft involving the signature artifact distinctions between form and matter and an antecedently conceivable form that is separable from its embodiment.

The efficacious form of the life process is something else. The living organism is continually reaffirming itself and in that respect it is the maker of itself. Yet this *auto-poesis* is not an exercise of *techne* or manufacture. As Kant will point out, every part of the organism is both means and end because every aspect of the organism functions for the perpetuation of a whole that includes itself. [28] So it not only serves as the means to the upholding of a whole but also it is an end because it thereby reaffirms itself. This inability to distinguish means and ends is fundamentally absent in artifacts. The distinct character of the living thing is directly on display in reproduction . The generation of the living organism does not occur by imposing form upon some inanimate material. Rather, generation involves what is already alive from which is engendered a separate living individual. Moreover, the generated living individual exhibits the power of enlivening material by assimilating inanimate and dead things, making them part of its own living metabolism . Further, the material of the organism is engendered together with its form, both of which undergo transformations in growth and metamorphosis.

All these features of the life process suggest that the conceptual resources required to comprehend an artifact will not be sufficient to conceive life. This problem would be generic to nature , if nature as a whole were to be thought of as something generated. If, however, we consider generation and efficacious form to apply only to the particular natural sphere of life, then one must address several additional questions. One must consider what is the relationship between this type of nature and inanimate nature ? One must also consider how inanimate nature

is to be conceived in distinction from both artifacts and life.

This latter question comes to the fore in examining the modern approach to nature that is crystallized by Kant. Foster's discussion of modern science's philosophical and theological underpinnings will help us focus on what is involved in the reduction of nature to mechanism and where in nature mechanism has its proper place . With that accomplished, we will be ready to tackle the universe in all its manifold complexity.

2.4 Theological and Philosophical Presuppositions of Modern Science

Before addressing with what the philosophy of nature must begin, it is helpful to comprehend what distinguishes the ancient and modern conceptions of nature , which each privilege categories that have legitimate application to different natural domains. To this end, we will draw upon the second half of Foster's essay, which sets in relief the distinctive philosophical and theological underpinnings of modern science. Thereby Foster provides a key handle on Kant's philosophy of nature and paves the way for understanding how Hegel recasts the ancient and modern paradigms into elements of a viable comprehensive concept of nature .

We have followed Foster's analysis of how Aristotle develops a philosophy of nature that fits the pagan conception wherein the divine is not radically distinguished from nature . Even though Aristotle conceives the divine as a self-thinking unmoved mover that is anything but natural, he ends up conceiving nature in terms of an active form that best suits the theological doctrine construing nature as the offspring of the divine rather than as the product of a divine demiurge. Although Aristotle conceives natural things to have an active form, as most evident in living organisms, he still wants to allow for a rational science of nature , in which natural things are definable and susceptible to necessary judgments and syllogisms. As Foster has shown, such intelligibility may be had by artifacts, which embody the inactive form of a concept. Can this intelligibility be retained by things that have an active form like a soul?

Can the philosophy of nature underlying modern science avoid this difficulty? Foster sets the stage for answering this question by turning to the theology that fits the modern philosophy of nature . Whether or not modern science depends upon a theological grounding, the theological understanding that corresponds to the presuppositions of modern science clarifies what these are.

Foster begins by identifying rationalism in theology. Rationalism in theology thinks the activity of God to be preeminently an activity of reason. [29] This view has as its corollary that when we humans engage in reasoning we are approaching what it is to be divine. We are able to think the thoughts of God to the extent that we can somehow restrict our activity to reasoning, ignoring the competing drives of our sensuous being that may lead us astray from thinking in a fully rational way.

Rationalism in theology might seem to have its most extreme advocate in Aristotle , who conceives the divine as thought thinking itself. Such thinking thinks about nothing extraneous to thought. It is a completely pure thinking and one might wonder how this could have any connection with nature . Can rationalism in the philosophy of nature offer a bridge?

Rationalism in the philosophy of nature consists in the doctrine that nature is essentially intelligible, that nature is conceptually transparent, that it is open to reason. This implies that even if we must use sensory experience to acquaint ourselves with nature , this is only a preliminary to guide us to the intelligible essence of nature , which is something very different from the contents that our senses and experience deliver to us. If we accept rationalism in nature , we acknowledge that there can be an a priori science of nature . We can conceive independently of experience what nature is universally and necessarily.

Aristotle is a rationalist in both his philosophy of nature and his theology. Accordingly, he presents his account of nature as something to be developed in the same way in which metaphysics is to be developed. Aristotle seeks to obtain knowledge of nature by uncovering its

first principles and then determining what can be derived from them. In so proceeding, Aristotle thinks of natural things as having natures which are determinative of how they function.

Aristotle , however, conceives of the divine as rational in such a way as to provide no bridge between the divine and the natural world. The divine as highest being is thought to owe its entire actuality to itself. It has no potentiality which would allow it to be open to determination from without. The divine, as completely self-actualizing, can have no matter, which would burden it with potentiality awaiting the external imposition of form. Rather, the divine must be entirely immaterial, which leaves it nothing but a thinking being. Moreover, to be completely independent, its thinking must be about nothing but itself. Further, this self-thinking must always already be what the divine is in full. To be purely actual and devoid of potentiality, the divine cannot change and can only think itself in an eternal unalterable self-conception. The rationality exhibited by the divine accordingly seems to have no application to nature for what the divine thinks in no way includes nature . The completely self-directed thinking of the divine thus seems to leave in question how reason can lay hold of nature . [30]

First of all, the self-thinking divine cannot determine the form of nature . The divine cannot exhibit formal causality with regard to nature because its activity provides nothing but the form of the divine itself. If nature has any form, it must be found somewhere else than in the divine.

Secondly, Aristotle ’s divine cannot provide any material basis for nature because self-thinking thought has no matter to offer at all. The matter of nature must either be independently given or derive from something other than the divine.

By the same token, the divine cannot wield any efficient causality with regard to nature or anything else. Efficient causality requires the capacity to change something else, but the self-informing activity of the divine is directed exclusively upon itself and operates in an unchanging eternal way.

Aristotle is left with only one other avenue for any connection between the divine and nature , and this is final causality. Aristotle does invoke the divine as the final cause of nature , but it is very questionable whether this makes any sense. After all, how can Aristotle ’s divine possibly be the final end for nature ? Given how the divine is characterized, how can anything serve either as a means or as an embodiment of it? Since the divine is pure actuality, consisting in the wholly independent activity of self-thinking thought, there is no way in which anything else can contribute to its realization. Moreover, there is no way that anything different from the divine can take on the constitution of self-thinking thought. Since thought that thinks itself has no singular character that could individuate one self-thinking thought from any other, it can have no plural embodiments.

Consequently, self-thinking thought seems bereft of any bearing upon nature . It would rather appear that Aristotle ’s conception of the divine repudiates Plato ’s notion that nature can be in some respect an offspring of the divine. This Platonic notion would at least provide an intelligibility to nature comparable to that of artifacts. A demiurge imposing form upon chaos to produce nature as an artifact would give natural things essences that are conceivable prior to and apart from their embodiment. Nonetheless, as Foster points out, nature , as produced by a demiurge, retains an element that is not properly rational. [31]

The activity of the demiurge does not just consist of thinking. It engages in an activity of making. Admittedly, this making is subordinate to the demiurge’s prior thinking of the form it is going to impose upon a given material. Still, imposing form upon matter is something distinct from an activity that is completely intelligent. The divine demiurge engages in both theory and practice, where the practice of making is dominated by and governed by theory. Nature that is a

product of such rational making has a sensuous or material element which serves as a means to the end of embodying the form. Experience is thereby left with a role very different from the one it enjoys with a modern science that considers itself to be essentially guided by an empirical element. This is because the end to be realized through the means of matter is not something that can be found in anything merely sensuous. It is something that can be preconceived in a completely intelligible way prior to any involvement with matter. Accordingly, it is not equivalent to the kind of general representation that empiricists offer us as the only type of universal that has any bearing upon existence. Such a general representation is what results when one abstracts commonly contained sensuous contents from a plurality of observations. As we have seen, when one deals with an artifact , the form common to a plurality of products is not sensuous but intelligible. This difference is exhibited in how archaeologists cannot know what they are dealing with simply by examining the sensuous properties of an object. The sensuous features of an entity do not provide an understanding of its function and form. One must know what the entity is to be used for and knowledge of its function depends on conceiving its form, which is intelligible prior to and independently of its embodiment.

Admittedly, when an artifact is produced, some given material gets shaped in the sense of having its physical configuration altered. Still, shape and form remain distinct. Shape pertains to the physical boundary or the physical contour of an object. Changes of such physical configuration can be identified by spatial-temporal measurement, just as physical composition can be identified by chemical analysis. In making an artifact , the artificer indeed employs physical and chemical processes to make it what it is supposed to be. Nonetheless, the object cannot be fully identified as an artifact by the physical and chemical alterations that enable the material of production to embody its defining form and function. The latter must still be thought of apart from these physical and chemical features. There remains an extra leap of understanding beyond sensuous observation that must be taken to get at what the thing is. Consequently, if the natural sciences were to operate in a manner appropriate for grasping things as if they were artifacts of a divine demiurge, observations would be used in a fundamentally different way from how science will proceed according to the canons of empiricism and its reliance upon induction from sensuous data. If nature is thought of as an artifact , one must move beyond the sensuous data and employ a cognitive activity different in kind from what one uses to take in the sensuous being of things.

Modern science can thus be characterized as breaking with rationalism in theology, ceasing to regard the divine as either strictly rational in the Aristotelian sense or as less strictly rational in the sense of an artificer. Instead, as Foster suggests, modern science can be thought of as operating on the basis of or at least in conformity with a view of the divine as having a voluntarist relation to nature . [32] Instead of regarding the divine to produce nature in an exercise of thinking or in an exercise of willing that is guided by thinking, this theological view regards the divine to engage in a willing of nature that is not guided by any preconceived forms or concepts. In this case, one cannot regard the physical presence of the world as the realization of something that is intelligible. The world is no longer the embodiment of any antecedently conceived ideas or the product of a making that is guided by such preconceptions. It might appear then that nature has become completely contingent upon a willing that is itself completely arbitrary because it is not guided by any rational element. Such would seem to be the case if nature were the result of an act of creating rather than an act of making, that is, if nature were a creation rather than an artifact .

If nature were such a creation, one would have to experience its sensuous being in order to

come know it. With nature created by a divine will that is completely unfettered by reason, the science of nature would have no a priori element. It would have to rely entirely upon observation and be purely empirical. Natural science would depend entirely upon induction and therefore never be able to establish any universal or necessary determinations of nature unless scientists surreptitiously take for granted the uniformity of nature .

Although Judeo-Christian and Islamic theology conceive of the divine as a creator and provide the general theological heritage from which modern science arises, it would be a mistake to think that modern science is devoid of any rational element, as empiricism might judge it to be. Rather, as Foster notes, there is a rational element in modern science that is set in relief by Kant. [33] Whether one turns to *The Critique of Pure Reason* or the *Prolegomena to any Future Metaphysics* , Kant unflinchingly maintains that modern physics, like mathematics, confronts us with a body of knowledge that exhibits universality and necessity, while providing us with "ampliative", "synthetic" comprehension. Neither of these sciences gives us just analytic truisms about what is to be found within certain given terms. Both instead connect different terms in ways that are still necessary and universally valid. This may be most obviously evident in the case of mathematics and geometry. Kant, however, does not hesitate to maintain that natural science confronts us with a body of synthetic a priori knowledge, ampliative yet universal and necessary. This might appear mysterious on Kant's own terms because he emphasizes over and over again that when we deal with things that appear to us in experience and rely only upon observation, we can never obtain any knowledge that is necessary or universally valid. Experience can never provide knowledge that can count as truly scientific, for observations are always contingent and particular, whereas science proper offers knowledge that is necessary and universal. Yet, as Kant affirms, in physics we have a natural science that does provide truths that have the same necessity and universality as those of mathematics. Not surprisingly, physics is the science that applies mathematics in a thoroughgoing way. Kant does not question *that* there is such an a priori natural science. Instead he questions, "*How* can there be such a science?" How can there be a science, be it natural or mathematical, which provides us with knowledge that is universal and necessary and yet is not merely analytic?

Foster lays bare the understanding of the divine that provides the theological underpinnings for such a science, and although we may be able to separate modern science from any theological moorings, the latter help define what the philosophy of nature contributes to such a science. Foster does not want to deny that modern science has an empirical side, but he insists that it also has an a priori side to it and we want to try to make sense of this, above and beyond Kant's own explanation.

A purely empirical natural science can easily be seen to issue from a completely voluntarist theology according to which the act of creation is an exercise of sheer will completely unguided by reason. Such creation issues in a nature that is completely contingent and natural science will accordingly have to rely upon induction and nothing more than induction.

There is, however, a different path specific to Judeo-Christian-Islamic theology, that makes theologically intelligible how there can be a modern science that has both a priori and empirical elements. In addressing this option, we need to consider the distinction between natural science and the philosophy of nature , for when natural science has an a priori element, one must ask to what degree is the science of nature something other than the philosophy of nature .

Certainly one can wonder whether the Aristotelian approach to nature allows for a natural science different from the philosophy of nature . Does modern philosophy, as epitomized by Kant, introduce a divide between the philosophy of nature and natural science, even while

securing an a priori element to modern science? When we consider Kant, we must ask what difference is there between the philosophical foundation of modern science and the natural science it purportedly grounds.

As we have seen, one way of providing for rationalism in natural science is by invoking a divine demiurge that makes nature as an artifact . The activity of the demiurge, however, has two limitations that circumscribe the resulting rationalism in natural science. As Foster points out, the demiurge, unlike a creator, must act upon a given material. [34] This condition imposes a limitation upon the intelligibility of the product, which is highlighted in Plato ’s doctrine of the forms. Namely, because the form is embodied in a given material, it can never be perfectly realized. As Plato insists, sensuous things can never completely exhibit the intelligible idea that informs them and makes them what they are. They remain imperfect reflections, imperfect replicas of their form. So, for example, we may have the intelligible idea of a triangle, but when it gets embodied, the edges of the real triangle are no more real lines than the triangle’s figure is without depth. Whatever the intelligible form may be, its imposition upon a given material always involves an aspect of defective, imperfect realization.

There is a further limitation to the activity of the demiurge, which is that the idea, the end or plan to be embodied, is given independently of the demiurge’s imposing of form upon its given material. The form is just as antecedently given as the material. As Foster points out, these two aspects of givenness go against the idea of an omnipotent divine, such as Judeo-Christian-Islamic theology embraces. [35] How then can nature be made by a divinity that retains omnipotence, yet is still able to fashion a nature that has something intelligible about it?

The resolution to this problem has two sides. On the one hand, the omnipotent divine must somehow realize what it puts into nature in a way that is completely perfect. On the other hand, what it puts into nature must be something that it has come up with on its own, not something that it finds independently given. These two requirements are met in the activity that has been characterized as intellectual intuition or intuitive understanding. [36] Here the theoretical activity of the divine is such that it constitutes its object of thought without any deficiency. This does not mean, however, that everything about nature is going to owe its being to the theorizing of the divine. We must keep in mind that Foster is here thinking through the kind of theological account that will make sense of what otherwise could appear to be incomprehensible—that modern science involves both an a priori element and an empirical element. By following the twists and turns in Christian theology, he helps us get a handle on the principal forms of modern science and the kind of philosophies of nature that underlie them.

Now to begin with, the omnipotence of the divine can be redeemed by thinking creation to involve this kind of intuitive understanding or intellectual intuition whereby nature is generated in the divine’s purely spiritual activity. To the extent that this way in which the divine engages in its thinking could also be exhibited in our thinking, we could attain the same complete rational activity. As Foster points out, this parallelism is found in Descartes , whose appeal to meditation involves the self-producing ideas through its own self-reflection as opposed to finding them through a contemplation of ideas simply given to it. [37] If nature is structured entirely by such ideas, the Cartesian can comprehend nature to be completely intelligible and susceptible of an a priori treatment for which any observations only serve as illustrations.

Now there is one other difference that Foster points to, which has to do with how the products of an intuitive intelligence do not embody forms, like the artifacts made by a demiurge. Instead, the nature issuing from intuitive intelligence is subject to law. The divine as intuitive intelligence produces a law-governed nature , not a nature comprising the embodiment of form.

This outcome reflects the notion of the divine as an omnipotent law-giver, whose law rules nature in a way that is both perfectly extensive and perfectly intensive. [38]

The divine law of nature will be perfectly extensive insofar as the law will have no exceptions. There will be no phenomena in nature that do not exhibit the law. Moreover the divine law of nature will have an intensive perfection whereby it will not be realized to a certain degree in natural things. Rather, it will be perfectly realized in nature , unlike forms that are exhibited only in defective resemblances. Here law will completely penetrate nature without exception. This conception thus accords with the kind of philosophy of nature that regards lawfulness to be exhibited in material reality without fail, allowing nature to be knowable a priori with the same kind of certainty and exhaustive knowledge as the objects of mathematics. [39]

As Foster points out, this conception of nature is basically akin to the kind of science that Descartes develops. [40] Although one might be tempted to think that this kind of science would have no empirical element, the corresponding theological conception insures that there be an empirical element, side by side with an a priori element. There are three grounds for this, which are reflected in three different philosophical approaches characterizing early modern philosophy up through Kant. [41]

To begin with, if one regards an omnipotent divine as a creator of nature who imposes law on nature , the law will be intelligible and allow for a science of nature that can think such law and find it confirmed without exception. Observation will not be the basis for the science but will supply illustrations of what reason determines. Nonetheless, even though the resulting law-governed nature is thereby rational and intelligible, there is still something that is not determined by law. Namely, the law imposed by the divine is itself contingent upon the decision of the divine to make law for nature . That decision is not itself dictated by any law. Rather, the enactment of the law of nature by the divine is an act of will. As Foster observes, this element of decision also applies to the demiurge who imposes form upon the chaos of unformed matter. [42] A demiurge may think the given ideas that are then going to be embodied, but that embodiment is still contingent upon a decision to impose those forms upon matter, a decision that is not necessitated by conceiving those forms. Although God here produces the world rationally by rendering it a lawful creation, the will to create it remains arbitrary. This arbitrary aspect of divine will is exhibited in the two sides of Cartesian philosophy, which acknowledges that God creates a world that is lawfully rational by an act of will. This entails that one can think the rational form or the rational law to which extended matter will be subject but that creation will contain something that one can only know by observation rather than reason. What observation can provide evidence for is that indeed *there is* a world, even though reason can determine thoroughly the lawfulness that will be exhibited ruling over all natural things to a perfect degree. Observation alone can confirm not why, but that there is a world governed by law. There is no why, because the being of creation is arbitrary, depending upon God ’s free decision to create.

Secondly, as Foster points out, there is a further element of voluntarism which affects how one regards nature and how science will operate. [43] Acknowledgment of this further element entails a departure from the Cartesian view, manifest in the distinction that Leibniz draws between possibility in general and compossibility. Compossibility brings into to play something that sheer possibility does not. What is possible, given that God creates a nature that is rational, intelligible, or lawful, is what is logically consistent, according with the law of non-contradiction. Possibility corresponds to what is thinkable, but not everything that is thinkable can coexist. There may be certain things that are thinkable that exclude other things that are thinkable. For that reason what can possibly coexist, what is compossible, is distinct from what is

possible in general. Consequently, there is a voluntarist element concerning not just whether there will be a nature that is lawful, but concerning what laws are going to be enacted, what intelligible determinations are to be part and parcel of nature . Although one could use reason to think through what are the possible forms of law that could govern nature , or, in other words, think through what are the worlds that are possible, knowing which possible world is actual will depend upon observation. Observation does not establish what the possible forms of law are. Rather, observation confirms which one of the possible lawful configurations that the world might have is actual. Thinking law does not establish that it is actual, precisely because there can be a plurality of possible laws, and only the arbitrary decision of the creator determines which gets actualized. Nevertheless, the theological notion of a lawful creator allows us to still retain the conviction that what is natural will have a lawful form, a form that will be determinative of everything in nature without exception and to a perfect degree. We will have to depend upon experience, however, for two things. First, only observation can confirm that there is a nature . Secondly, only observation can confirm which possible world is actual.

Admittedly, as Foster notes, Leibniz himself violates the very distinction between possibility and compossibility with his notion of theodicy, according to which the world is necessarily the best of all possible worlds. [44] Leibniz maintains that the divine cannot help but will the best of all possible worlds. Due to the perfection of God , the divine will must be guided by the idea of the good. If that is the case, however, the distinction between possibility and compossibility is destroyed for, in effect, nothing is really possible except what is best. The notion of theodicy thereby eliminates the voluntarist element on which the plurality of possible worlds depends.

Without theodicy, both voluntarist elements remain in effect and their presence is exemplified in the scientific practice of Kepler. As Foster points out, Kepler worked out different mathematically possible a priori schemes for planetary motion and then relied on observation to find which one was operative in our solar system . [45] He was certain it had to be one or another, so once observations proved to fit one such scheme, its scientific validity was assured.

Now there is one further element of contingency in created nature where voluntarism enters in and this element brings us to Kant. [46] This third voluntarist factor provides an important insight into how Kant conceives nature as well as into how natural science can have both a priori and empirical elements. Not only is there a contingency regarding the existence of nature and what law governs the universe. There is an additional aspect to nature that escapes the grasp of reason and this concerns how the universality of law cannot take hold of all that is. What is at stake here is something that applies to universals in general, whether they be expressed as law or as form. There is no way a universal can take hold of everything that is because everything that is has individuality . This means that there is going to be an additional element in nature that is not going to be determined by reason or, theologically speaking, by a divine rationality that would be governing creation. Accordingly, observation will be required not just to confirm that there is a nature and, secondly, that nature has the type of law it has. Even though nature will have a lawfulness, that lawfulness will not determine the particularity that nature will also have, insofar as natural things are individuals. To get at that individual aspect of natural things requires observations. Science may get at the lawful configuration of nature in an a priori way, but the individual realization of that law will not be accessible without recourse to observation. This does not make an a priori science impossible. It rather indicates that an a priori science will be restricted to the lawful form of nature .

This understanding is, as Foster notes, exemplified in Kant’s approach to nature . [47] What operates like a divine intuitive understanding, with the three voluntarist limitations sketched out

above, is what Kant identifies as “transcendental understanding”, namely the structure of knowing that is determinative of knowable objectivity or nature . It will determine the lawfulness of objectivity. It can only determine the lawfulness of objectivity because the structure of knowing in question is “transcendental” insofar as it is determinative of what is knowable about any object whatsoever. It mandates the necessary and universal aspects of objectivity or nature , which apply equally to all objects. As such, it is a lawful necessity, which applies to every natural thing no matter what it is. It is thus a law that applies to natural entities with respect to their matter rather than to their form or specific “nature ”. That does not mean that natural things are merely matter. As Berkeley showed, things cannot be experienced just as matter, for one cannot experience tasteless, invisible, inaudible, odorless matter. One cannot encounter any of the so-called primary qualities, the purely material spatio-temporal determination of natural objects that early modern philosophers take to be what alone is truly objective and truly objectively knowable. None of these primary properties can be encountered except through the sensuous qualities of so called secondary properties. In other words, the nature we encounter cannot be just matter in motion. Nature has to be further determined and this requirement is endemic to the very framework of mechanism .

In mechanism , factors are determined solely by efficient causality, a causality indifferent to the form and import of those factors. The framework of mechanism presupposes that there are a plurality of objects, of individual bodies. What provides for their individuation? The laws of matter cannot do that since they apply to all things equally, without distinguishing them as individuals. So there must be in principle further kinds of determining in nature . Are all aspects of that further specification only determinable by observation or does that specification involve necessary features that reason can uncover? Will the philosophy of nature have more to say about nature than what is merely material and subject to the laws of motion?

The preceding considerations provide a road map of the chief approaches of the modern way of addressing the divine and nature . We will see that the distinguishing features of these approaches will be instructive as we move on to tackle how the various aspects of nature are determinable.

Notes

1. Michael B. Foster’s work has been unduly neglected. His book, *The Political Philosophies of Plato and Hegel* (Oxford: Oxford University Press, 1935), provides remarkable examinations of Plato ’s *Republic* and Hegel’s *Philosophy of Right*. His hard to find short book, *Mystery and Philosophy* (London: SCM Press, 1957), complements his essays of the 1930’s on theology, science, and the philosophy of nature .

2. Michael B. Foster , “Christian Theology and the Modern Science of Nature “, Part I, *Mind,* Vol. XLIV, No. 176, October 1935, pp. 439–466; Part II, *Mind,* Vol. XLV, No. 177, January 1936, pp. 1–27.

3. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 439.

4. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 440.

5. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 440.

6. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 440.

7. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 441.

8. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 442.

9. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 444.

10. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 445.

11. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 445.

12. Foster draws and develops the following distinctions. See Foster, “Christian Theology and Modern Science of Nature ”, Part I, pp. 446–449.

13. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 447.

14. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 449.

15. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 449.

16. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 460.

17. This will prove to be important for modern science and its reduction of nature to a mechanism .

18. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 461.

19. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 461.

20. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 462.

21. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 462.

22. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 463.

23. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 464.

24. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 464.

25. Foster, “Christian Theology and Modern Science of Nature ”, Part I, p. 464.

26. Aristotle , *Physics*, Book II, Chap. 8, 199b30, in J. Barnes (ed.), *The Complete Works of Aristotle* (Princeton, NJ: Princeton University Press, 1984), I, p. 341.

27. Aristotle , *Physics*, Book II, Chap. 8, 199a12–15, in *The Complete Works of Aristotle* , I, p. 340.

28. Kant, Immanuel , *Critique of the Power of Judgment*, trans. Paul Guyer and Eric Matthews (New York: Cambridge University Press, 2000), 5: 373–374, p. 245

29. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 1.

30. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 2.

31. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 2.

32. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 5.

33. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 7, 12–13.

34. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 6.

35. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 7.

36. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 9–11.

37. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 10–11.

38. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 15.

39. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 14.

40. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 10–11.

41. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 19ff.

42. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 19.

43. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 20.

44. Foster, “Christian Theology and Modern Science of Nature ”, Part II, footnote 1, p. 20.

45. Foster, “Christian Theology and Modern Science of Nature ”, Part II, p. 21.

46. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 26–27.

47. Foster, “Christian Theology and Modern Science of Nature ”, Part II, pp. 26–27.

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3. How and Where to Begin Conceiving Nature: Three Fundamental Options

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One of our abiding concerns is to comprehend how what distinguishes the philosophical projects of Aristotle , Kant, and Hegel determines how they tackle nature . Our primary interest lies in addressing what nature is and how nature ought to be conceived, but it would be foolish not to draw upon all three of these pioneers in the philosophy of nature whenever warranted.

3.1 The Aristotelian Approach to Nature

Aristotle brings to classic development the fundamental approach of philosophy that begins with an attempt to know what comes first in being. This approach seeks what is not constructed, what is not mediated by anything else but what constitutes that on which everything else is grounded and that which has to be known before anything else can be known, being what is most universal. The investigation of what comes first and is determinative of everything and thereby most universal, has come, oddly enough, to be called “metaphysics ”, what comes after physics, the science of nature . This label contradicts the very character of this primary investigation because it cannot follow physics properly speaking. Metaphysics , as the science of what comes first, of what is determinative of everything else, of being qua being, is an investigation that precedes the philosophy of nature , as well as every other particular field of philosophy. Nonetheless, physics is what comes next, what comes second. The philosophy of nature presupposes nothing but metaphysics , the investigation into being per se, precisely because the first type of being that can be studied solely on the basis of comprehending being in general is nature . The investigations of everything else will be predicated upon the comprehension of being as well as nature , because everything else will in effect be dependent upon and involve nature . This is true of ethics and politics, poetics, rhetoric, and anything else deserving of philosophical investigation.

Whatever the topic, the Aristotelian approach seeks what comes first and thereby aims at uncovering the first principles that apply to the domain in question. The philosophy of nature will here require getting at the first principles of nature . These may be spoken of as the first causes, the fundamental determining principles of nature . In addition to this there is another aspect about what comes first that Aristotle upholds in his investigation of being. There he argues that what comes first is ultimately substance, on which all relations and qualities depend. Substance is that which underlies all such other subsidiary, secondary features. Hence, in nature , as in other spheres of being, a fundamental, primary substance or subject is pre-supposed by all other determinations.

Substance itself will be what is determined in terms of the various types of causality. Formal, material, efficient, and final causalities will all come into play. Aristotle , however, points out that in nature , three of these causes will go together. [1] In effect, these three types of causality will be combined in one and the same factor.

What are they and why are they together? Significantly, the three do not include material causality, which figures so prominently in the early modern mechanistic view of nature . Rather, the three causes that fall together in nature are formal, efficient, and final causality. They all are combined in nature insofar as the form is also both the end and the moving principle of natural substances. This falling together of these three causes exhibits how Aristotle takes form in nature to be a self-acting, self-perpetuating, self-realizing form. Or, to use the term that Foster applies to this type of form to distinguish it from the passive form embodied in an artifact , form in nature operates as a soul.

Form as soul comprises the first, three-fold principle of nature . Significantly, in *De Anima*, “On the Soul”, Aristotle characterizes the soul as being the principle of life. [2] This is indicative of how the principle that Aristotle uses to distinguish nature from other forms of being seems equally to distinguish a particular sphere of nature —namely that of living things. By distinguishing nature as a particular kind of being, characterized by an active form that wields

formal, efficient, and final causality, Aristotle has rendered nature as a whole something ensouled. In so doing, Aristotle has identified nature per se with how life is preeminently characterized. Nature , Aristotle , maintains, is that which is self-moving. Therefore nature always involves change. If, however, the change is dictated by nature 's own form, the change is not dictated by any external factor. This contrasts radically with any natural system of mechanism , in which the change of things is determined externally, with complete indifference to their specific natures. Nature here may still have room for chance in respect to the external juxtapositions of things, but fundamentally what is by nature involves substances being subject to changes whereby they move themselves in virtue of what they are, which is also that for which they exist.

Aristotle describes how formal, efficient and final causes coincide in nature in Chap. 7 of Book II of the *Physics*, writing, "for the what and that for the sake of which are one, while the primary source of motion is the same in species as these." [3] Although this coincidence is supposedly generic to nature , Aristotle illustrates it with examples that are predominantly biological. Indeed, the examples he offers are generally animals, for it is harder to find plant life exhibiting self-movement in a full-fledged way.

It is noteworthy that in Chap. 8 of Book II of the *Physics* Aristotle introduces the idea of evolution so as to unveil its untenability and thereby lend support to final causality and self-motion in nature . [4] He presents the option that things in nature have come to be the way they are through a completely blind and accidental necessity where living things undergo random transformations enabling those to survive that turn out to be most fit. The resulting development is not guided by any end, nor does it move itself, but it gives the appearance of being purposive, since the victors of the struggle for survival seem to have an intrinsic superiority. Aristotle dismisses such evolution, pointing out that what happens invariably or for the most part is determined by the nature of the factor that undergoes such change. The change is motion in the broad sense of alteration, rather than the narrow sense of locomotion or change of place in time . We may be used to thinking of motion, or *kinesis*, as just being locomotion , which reflects the truncated view of early modern science , for which all change in nature is ultimately reducible to movements of matter. For Aristotle , motion has various dimensions, involving not just how matter alters its position in space and time , but qualitative and purposive aspects. The key point is that in nature the changes that take place happen for the most part and what happens for the most part is necessitated by the form of natural things, a form that is self-moving and self-sustaining.

Why would the change of natural process be something that will happen invariably? Why would the principles of nature , which determine nature not just materially, but also with respect to form, efficient causality, and purpose, end up being by and large the same factor?

Admittedly, other things might prevent natural movement or development from occurring. A living thing might be prevented from carrying out its life functions by disease, by the intrusion of other organisms, by changes in weather, or by other external circumstances.

One might be tempted to add that the material might be defective and unable to fulfill its function. Yet how can we differentiate defective from fit material? To do so requires that the matter in question already have a determinate form, rather than being a pure potential. Certainly, material may be of a certain kind, e.g., wood, and thereby be suitable for particular functions insofar as it will have a determinate potential to take on certain specific forms rather than others. Indeed, to be actual in any respect, material must be formed in some way, rather than being indeterminate in general. Consequently, any existing material will not have an indeterminate

potential, but rather be subject to a range of changes owing to its specific character.

Aristotle does speak of monstrosities in this connection, pointing out how the process of nature gives rise to things that do not quite fulfill the end to which their form should lead them. He explains this by referring to how in art, artisans often fail to operate in a technically proficient manner. Mistakes are made and in just this way, nature makes mistakes of its own. [5] This example is another case where Aristotle attempts to explain what happens in nature by making an analogy to craft, as if the self-motion of natural things could be equated with the manufacture of artifacts. To carry through the analogy, the activity of the craftsman must somehow be contained within the objects of nature , allowing them to be self-active in a manner that encompasses the imposition of form upon matter. As we have seen, this analogy breaks down, for even in the case of the self-curing doctor, the healthy life process does not include the intervention of medical craft, which is needed to cure disease and reestablish the natural harmony which itself has no place for medical practice.

Although Aristotle maintains that nature involves change dictated by what form natural things have, what end they realize, and what efficacy they wield, he still suggests that locomotion has primacy with respect to the other types of change. [6] Locomotion is primary because the other kinds of change cannot occur unless some sort of locomotion is at hand. In other words, some alteration in place and time will be involved when a thing undergoes some change in function of its form or end. That does not mean that every change is reducible to locomotion . Rather than introducing any kind of reductionism to efficient causality, the primacy of locomotion simply provides the occasion for the operation of the other forms of causality.

3.2 With What Should the Philosophy of Nature Begin?

With what then, should the philosophy of nature begin? On one point, Aristotle , Kant, and Hegel are agreed—what the philosophy of nature begins with is not that with which philosophy begins. For Aristotle , philosophy begins not with physics, but with metaphysics —the investigation of being qua being. For Kant, philosophy does not begin with a presentation of the metaphysical conditions of natural science, but with a critique of pure reason. And for Hegel philosophy does not begin with the philosophy of nature but with what he will characterize as a science of logic, an effort to do philosophy presuppositionlessly, dealing with determinacy in general as opposed to the determinacy of nature or the determinacy of mind. For all three philosophical pioneers, the philosophy of nature is intermediate. It follows after some other primary investigation and then is followed in turn by further investigations that will address the reality of and products of rational agency, thereby grasping the kind of being that can philosophize about nature .

As for that with which the philosophy of nature should itself begin, there is a general agreement that the proper starting point consists in that aspect of nature that does not rest upon other natural factors, but is that on which everything else in nature depends. This starting point is accordingly that which is most universal in nature , that which is at hand in all natural entities, while not itself resting upon any particular aspect of nature . It can be said to be what is most formal, most abstract, and least concrete in nature . What is this primary natural factor, to which each of our three pioneers first turns? Not surprisingly, they all begin by addressing space and time .

In so doing, however, Aristotle , Kant, and Hegel do not address space and time in the same way or in the same order. The discrepancy of their treatments raises the general question of whether these most general and abstract aspects of nature are equally primordial. Are space and time coeval or does one come first, and if so, which?

3.3 Aristotle ’s Privileging of Place as Primary

Aristotle addresses this general topic in Book IV of the *Physics*. He considers what has to do with space and what has to do with time in a very particular manner. Namely, he focuses upon place and it is important to consider what is distinctive about considering place rather than space to be primary. Both Kant and Hegel make a point of distinguishing place from space. Hegel in particular considers place to be something that cannot be or be known apart from space as well as time .

What is at stake in Aristotle ’s privileging of place ? He opens Chap. 1 of Book IV of the *Physics* by maintaining that the investigator of nature must have knowledge of place . Why? Everyone recognizes that what exists must be somewhere, in a place . Furthermore, all motion is or is bound up with locomotion , which is change in place . [7] Insofar as nature is self-moving, place will be at hand with all natural things. Place is a universal feature of all natural things, which themselves involve substance. Natural substance will be in a place and any motion natural substances undergo will be in reference to place .

It is important to reflect on how Aristotle considers motion, signifying change in its most general sense, to ultimately involve change in place . Can locomotion , however, be primary? Locomotion can occur without change in form or change in import. Must change in regard to form and end, however, rest upon change in place ? If it does, then indeed everything about nature will involve place since place is connected to motion and nature is that which moves itself.

All these considerations carry with them a connection that underlies place and makes place something that Hegel, for one, cannot consider a proper starting point for the philosophy of nature . Namely, place is from the outset associated with an existing entity, a natural thing. [8] This natural thing is not just a body , not just matter in motion. It is something in motion in the full-fledged sense of being subject to the changes exhibiting all the causes tied to the active form of natural entities. As we shall see, Hegel will maintain that there can be no place without space and time and a unity of both, which will be the basis for matter and motion. By beginning with place , Aristotle equally begins with physical entities that involve motion in the general sense in which nature comprises the domain in which things move themselves in function of what they are. Here the same factor is the formal, efficient, and final cause, and place , Aristotle ’s rudimentary spatial determination, is directly associated with the presence of natural substances and the motion that is endemic to them. [9]

What then is place ? As Aristotle observes, the answer is not so simple and has tended to elude thinkers prior to him. [10] There is a common recognition that place is bound up with natural substances, but it is also recognized that place cannot be identical with them. If place were identified with a natural thing, there would be two things in the same place , for the thing occupies the place , but is not itself the place , which remains when the thing moves from it to another location.

A place can be occupied by different things at different times, and perhaps it can be unoccupied, or rather, occupied by a void . A thing that undergoes locomotion changes its place , but the places it traverses do not move, but stay put. They remain what they are. Accordingly, place is connected to things and yet is different from them. Aristotle insists that place is not relative, but one is tempted to think that what is right or left or up and down is relative to the respective location of different things. [11] Place and location seem indistinguishable, and both

appear indeterminable without reference to the things that occupy them. Aristotle , however, maintains that place has an absolute, non-relative determination, which, as we will see, contrasts markedly with what Kant and Hegel will have to say about space, time , and location or place .

What anchors place in an absolute fashion is the connection between natural substances and place . Namely, the fundamental different types of natural substances have a natural place to which they move themselves in function of their defining form. In this respect, place , Aristotle observes, exerts an influence upon natural things, an influence that is internalized in their distinctive natures, which move them to different places with respect to what they are. [12] Both Kant and Hegel will insist on the contrary that place or location is indifferent to the things that occupy it and this indifference is directly connected to a very different way of characterizing motion.

Basic to the Aristotelian conception of place is place ’s connection with natural substances that move themselves in respect to their form and import. On this basis, what is earth will descend to a place that is objectively, absolutely down, whereas what is fire will ascend to a place that is absolutely up. Through such connection to natural things and their distinctive motions, place can manifest its absolute character. Nonetheless, Aristotle maintains that “things need to have space first” insofar as “everything is somewhere and in place …. then the power of place must be … prior to all other things.” [13] Without place , no natural substances can exist and without natural substances no natural relations or qualities can be. Yet place is not a relation of natural things, for place does not pass out of existence when things in it are annihilated. Place remains.

Aristotle speaks of two kinds of motion (i.e. change) that seem directly related to place —locomotion and change in size. [14] Locomotion obviously involves place , since it is defined by something changing its place in time . Increase or diminution may not involve any change in place of a natural substance, if one identifies its place with a central point. If, however, place comprises the boundary of a natural thing, that boundary alters when something increases or diminishes in size. By connecting increase and diminution to place , Aristotle is obviously considering place not as the central point of a thing, as in a center of gravity , but rather as the bounded space containing natural entities. Significantly, Kant will first discuss physical space in reference to points, from which moving forces can emanate. Here, in Aristotle ’s *Physics*, from the very onset space is determined in terms of place , in reference to an actual substance with respect to types of motion: locomotion and change in size.

Accordingly, Aristotle defines place to be the innermost motionless boundary of what contains a natural substance or “the boundary of the containing body at which it is in contact with the contained body .” [15] One might wonder whether this definition has any ramifications for how Aristotle addresses time . Place , viewed as the innermost motionless boundary of what contains a natural entity, seems to leave time aside. Aristotle , however, speaks of place in connection with actual natural substances, which can be moved. [16] Although movement may involve other types of change than locomotion , locomotion still figures as their enabling condition. Since locomotion involves change of location over time , temporality seems to be in play in place .

How then, does Aristotle characterize time ? He raises the problems that perennially haunt any attempts to conceive temporality. First of all, does time exist? Time appears to have the peculiar character of consisting of elements that themselves do not exist, whereas what exists ordinarily exists only insofar as its parts exist as well. Time , however, involves a “now” that straddles the past and future, where the past no longer is and the future is not yet. So we confront

something that is composed of elements that seem to lack existence. [17]

Further, time is associated with motion, be it change in general or locomotion in particular. Aristotle observes that time seems not to exist without change and change does not exist without time . Nonetheless, even if time may not be independent of movement, time is not movement. [18] Still, time is here being conceived in conjunction with motion and motion, rooted in locomotion , obviously involves place . Further, place involves reference to some physical entity or substance subject to change. Accordingly, the conception of time will be bound up with all these factors.

These considerations may seem commonplace, but they contrast markedly with how Kant and Hegel will think about time . Both of them will maintain that space and time cannot originally be relations of or elements of physical things. If space and time are instead conceived as bound up with physical things, one ends up running around in circles, for the most basic reality of physical substance, matter, cannot be without presupposing space and time .

Space and time are both required for matter to be for the following simple reasons. The reality of anything in nature cannot be or be thought of if it does not occupy space. It cannot just be a geometric point, but must fill some determinate volume. Moreover, it cannot fill anything in an appreciable way unless it does so with a determinate duration. Otherwise, it is just present in that volume for an instant, which renders it no more existent than nonexistent. The very presence of something in nature therefore requires both space and time , not just as supplying points and moments, but as involving a universal space and universal time that has determinate extension and determinate duration, each encompassing particular points and moments. Hence, just as place is not the thing it contains, so time is not the movement that proceeds in time . We may perceive movement and time together but time has an abstract being that movement presupposes and then concretizes.

Aristotle presents two alternatives: either time is movement or it is something that belongs with movement. “Time is not movement” but something that belongs with movement insofar as movement “admits of enumeration”. [19] Time is what discriminates movement. Time here functions as a kind of number, insofar as it allows movement to be quantified, “for time is just this—number in respect of ‘before’ and ‘after’”. [20]

Further, Aristotle notes, the now is in one sense the same and in another sense not the same. [21] The now is now and then it is gone. But, as soon as the now is no longer, there is another now, subject to the same disappearance and replacement. Time furnishes all of these now’s in succession, a succession in which they are both the same and different. They all have the same substratum, which supports their succession.

What is the substratum upon which all moments of time rest? Aristotle suggests that it is the body that is in motion. [22] The now is found in it at every instant of its motion. The substance in motion is what unifies the moments of time , carrying along the enumeration that time involves. In this respect time is itself bound up with natural substance that moves itself. Still, time is not identical to the substance in motion any more than place is identical with occupying place or entering or leaving place . Accordingly, Aristotle describes time as the number of motion with respect to before and after. [23] This number of motion is continuous, given how there is nothing really keeping the different now’s apart. Every now is different from that which comes before or after, but they are equally indistinguishable and both aspects are at play in the passage of time .

How then can time be measured? We measure time by movement. But how do we measure movement? We do it by time . Time and movement presuppose one another, insofar as they define one another. This circularity does not disturb Aristotle . He is willing to put up with this. Time is presented as the measure of motion and rest, such that time is connected with motion and

the lack of motion, just as motion and rest are associated with what occupies place : material substance.

All these factors are tied together with time , which, on Aristotle ’s account involves actual substances that exist in motion or rest, in some place or leaving one and entering another. One might ask, will time then cease if there is no motion? Since time seems to be tied up with motion, only ceaseless motion will guarantee that there will be no cessation of time . As Aristotle notes, time will surely not fail “if motion always exists.” [24] Circular motion is, Aristotle observes, the type of motion that is considered to be eternal and is, not surprisingly, the motion most appropriate for measuring time . [25] What thus ensures, accordingly to Aristotle , that time is eternal and eternally measurable is the ceaseless circular motion of the heavenly bodies. [26]

The continuity and the regularity of time will thus depend on an eternal regular motion and circular motion can have this character, unlike other types of motion. Clearly, this determination of time , like that of place , involves a very concrete point of departure, which will be contested in various ways by both Kant and Hegel. In turning to Kant’s construal of space and time , we will need to address his challenge to Aristotle and consider anew with what the philosophy of nature must begin.

3.4 The Kantian Approach to Space and Time

The second fundamental approach to philosophy, which Kant pioneers, calls into question doing ontology as first philosophy and immediately searching for the first principles of what is. Instead, knowing must first be investigated, making epistemology rather than ontology foundational for knowledge of nature . This approach only makes sense if the knowing that is investigated determines the character of the object of knowing. Only then could an investigation of knowing bear upon whether knowing has any truth, whether knowing can correspond to its object. This proviso tells us something fundamental about the whole enterprise of critical philosophy and how it must conceive nature .

The transcendental turn inaugurated by Kant has a basic logic that is followed by everyone who does foundational epistemology , no matter how differently they characterize knowing. They may construe cognition in terms of language, considered either as ideal or ordinary, or portray cognition in terms of consciousness , not as something extracted from the world it confronts, but as a concrete consciousness embedded in the world, such as Heidegger and other existentialists maintain. The key point that all such undertakings share in common is that their investigation of knowing is intended as a preliminary that is supposed to certify cognition before conceiving objects themselves. In Kant's case, the critique of pure reason is to be followed by a metaphysics of nature and a metaphysics of freedom . These are the two domains that a certified reason will now have to explore.

Nonetheless, the "preliminary" critique of knowing cannot help but contain within itself a determination of objectivity, providing in outline what any subsequent metaphysics of nature will elaborate. Since the transcendental investigation of knowing can assess the truth of knowledge only if the object of knowing is determined by the structure of cognition, it should allow us to know a priori what our cognition puts into objects in general. Accordingly, the critique of knowing will already provide a doctrine of knowable nature , prefiguring what is supposed to be unveiled once cognition receives certification. What follows the critique of knowing under the rubric of the metaphysics of nature and the metaphysics of freedom, is really nothing more than an explication of what is to be found in the initial examination of knowing.

Furthermore, because transcendental investigation or foundational epistemology leaves knowable objectivity determined by the structure of knowing, objectivity takes on a very specific character. To begin with, the object of knowing is, as such, subject to determination from without. Objectivity will not be a domain of things that do what substances should do in Aristotle 's nature , namely move themselves. Rather, objects are subject to an external necessity. Moreover, objects are all determined by the same necessity no matter what they are because every object is determined by the same structure of cognition. Things will thus be determined necessarily not in virtue of what distinguishes them from one another, not in terms of their specific nature , that is, not by their genus or species . They will rather be determined of necessity with indifference to what they are. The necessity lording over things will lord over them equally irrespective of what differentiates them. Accordingly, nature will be identified by Kant as being an objectivity governed by law rather than by essential form and hierarchies of genus and species . [27] That is what nature must be insofar as objects are determined by the structure of knowing. Nature is a law-governed objectivity, where necessity is external and the same for all things. Since objective necessity is indifferent to the specific form of objects, nature is governed by material law. The laws of nature apply to matter alone and this restriction very

much limits what can be known a priori about nature .

In the *Critique of Pure Reason*, Kant offers, under the heading of the "System of all principles of pure understanding", [28] a set of laws that determine objects of experience no matter what they are. These principles are all tied to the categories that Kant introduces in relation to the forms of judgment. These forms of judgment are shown in the "Transcendental Deduction of the Pure Concepts of the Understanding" [29] to play a necessary role in connecting our representations, enabling them to convey something objective while fitting together within the unity of self-consciousness . Judgment connects representations in a non-arbitrary fashion, affirming their objective, necessary association. The different forms of judgment each convey a different way in which objects are necessarily determined through non-subjective combinations of representations. The categories, which each capture the type of combination characterizing a form of judgment, do not specify types of objects. Instead of determining different natures or forms of things, the categories specify the different possible ways in which representations can be necessarily connected so as to convey some objective relation that applies to any object of possible experience. Rather than placing objects into a hierarchy of genus and species , these categories determine connections that objects must exhibit, no matter what they are.

Significantly Kant does not provide any derivation of these categories themselves or of the forms of judgment in which they are rooted. He simply puts them before us with the assurance that Aristotle has more or less figured out what they should be. Kant does admit that he has somewhat deviated from the specifications of Aristotle 's logic, but Kant does not offer much in the way of justification . [30] In fact, he even goes so far as to say that we really cannot define what the categories are because they determine the judgments that must be used in explicating their meaning. Any attempt at definition would thus be going around in circles. So we cannot say much about what these categories really are, let alone why just these are necessary. Basically, Kant tells us to take it or leave it. [31]

Nonetheless, it is no accident that Kant employs the particular categories that he sets out without further ado. This is most evident in the section of the *Critique of Pure Reason* where he introduces the Doctrine of Principles, which contains the basic laws that are determinative of any objective experience whatsoever. Kant does distinguish between two types of experience, one which employs "outer sense", involving spatial intuitions, and another which employs "inner sense", involving only temporal intuitions. [32] Inner experience pertains to psychological phenomena, which are temporally but not spatially ordered, whereas outer experience pertains to non-psychological phenomena, which are both temporally and spatially ordered. All the categories and the principles that follow from them are supposed to apply to objects in general. It turns out, however, that Kant will develop these principles in such a way that they really only apply, or at least all of them only apply, to objects of so called "outer sense", that is spatial, non-psychological objects. Consequently, the pure principles of experience end up being the a priori principles governing nature in general or objectivity in general, with nature and objectivity understood to be non-psychological in character, applying to the objects of "outer sense".

These fundamental laws of nature are quite minimal and can be stated very quickly. First, all physical phenomena have extensive and intensive magnitude. Second, all physical objects that can be experienced are substances that endure. Third, all change that can be experienced consists of alterations of existing substance rather than in the coming to be or ceasing to be of substance. Fourth, all alterations are causally determined in the sense of efficient causality. That is, objective events are determined by antecedent states of affairs in a way that has nothing to do with what the respective objects of those states of affairs may be. Finally, fifth, all coexisting

objects reciprocally determine one another, once more in terms of efficient causality. That is the entire specification of what could be called the principles that determine objects of experience and it turns out that the objects in question are all objects of outer sense, that is to say, objects conveyed by representations that are spatial as well as temporally ordered.

In the *Metaphysical Foundations of Natural Science*, [33] Kant is allegedly undertaking the Metaphysics of Nature for which the *Critique of Pure Reason* supposedly paves the way. Kant is attempting to go beyond the bare bones of the Doctrine of Principles to lay out whatever other a priori laws of nature can be provided. Although his task is essentially a further explication of what is already contained in the principles provided for in his preliminary transcendental investigation, he tells us that what he is here about to develop is based upon something that is not part of the investigation of the *Critique of Pure Reason* proper. The *Metaphysical Foundations of Natural Science* does not fall within the investigation of what holds true of objects in general insofar as they are determined by the structure of knowing, because it involves something that is empirical in character. Specifically, this secondary treatise operates on the basis of the specific kind of empirical content in our intuitions of outer sense. This particular empirical content will be the source for the additional laws that this investigation is going to establish. Although this content is alleged to be empirical, it is still going to underlie a priori laws that will hold true of all natural things that are susceptible to scientific treatment, in the proper sense of the term. The content in question, which Kant here supposes to be merely empirical, is matter. [34]

Matter will be the lynchpin for bringing in force as a factor in nature . We will see how Kant's dynamic conception of matter will tie force to matter and render the laws of matter laws of force. First, we need to consider Kant's claim that matter is something merely empirical in content. That claims helps explain the seeming mystery of why Kant maintains in the *Critique of Pure Reason* that force cannot be brought in an a priori way into the causal law and reciprocal causation of coexisting physical substances in the Doctrine of Principles. [35] The alleged empirical character of matter is traced back to the contrast between the material and the formal elements of experience. The formal elements of experience, the elements of experience that owe their determination to the structure of knowing, are twofold. They comprise, on the one hand, the forms of intuition, space and time , and, on the other hand, the forms of understanding, lying in the categories that specify how representations are ordered by the different forms of judgment. Allegedly matter is not part of those formal elements of experience. Matter is not dictated by the categories, nor is it bound up with space and time as forms of pure intuition.

Kant's demarcation of matter as empirical from the formal elements of experience immediately signifies that space and time are somehow to be determined apart from matter. This stands in stark contrast to how Aristotle conceives of space and time in terms of place and motion. Kant instead associates physical matter, as well as force, with "the matter of sensation," the filling of sensation, which only comes to us as an element of experience insofar as it is ordered by the common structures of cognition, the forms of intuition, space and time , and the forms of judgment, encapsulated in the categories. It is allegedly only in the content, the filling of sensation, where matter is to be encountered. Matter is delivered to us by the content of sensation, which is contingent. It retains the residue of the givenness of receptivity, which is not determined by the structure of knowing, but nevertheless somehow enters into knowing, providing the element of existence.

What is peculiar about this claim is the character ascribed to matter and the general way in which it is construed. When one considers what holds a priori regarding objects as they can be experienced, one is addressing whatever holds necessarily and universally of objects one can

possibly observe. Whatever holds necessarily and universally of objects has to be something determined a priori because observation, being always particular and here and now or there and then, can never establish what is universally, what is necessarily the case. Is, however, the materiality of objects of outer sense anything other than what holds universally and necessarily of any such objects? Are the forces that Kant himself will argue pertain to matter anything other than universally and necessarily the case for any physical things that we can experience? Kant does maintain that they are universal and necessary in nature as we can know it. Even though matter and force allegedly involve empirical content, Kant is still confident that we can obtain necessary and universal knowledge about physical things because we will be applying the forms by which knowing determines the structure of objects to a specific kind of object, namely, non-psychological objects with a material, physical nature . In doing so, we are now adding one qualifying feature that was supposedly not present in Kant's *Critique of Pure Reason*. The Doctrine of Principles allegedly determines all of the objects of experience, including psychological as well as spatial, material objects. Here, in the *Metaphysical Foundations of Nature* , those principles are to be applied to a type of object, distinguished by the supposedly empirical factor of matter. As already mentioned, however, Kant himself admits in the *Critique of Pure Reason* that the principles really only entirely apply to spatial things. [36] This should indicate that the materiality of spatial things is not merely an empirical feature of "outer experience", but something just as a priori as the "formal" aspects of cognition.

The non-empirical character of matter is something that was already acknowledged in the controversies among the classical Empiricists. Locke recognized that matter is not something one finds in the sensuous matter of our intuitions, because matter is something completely abstract. Matter is that tasteless, smell -less, soundless substrate supporting all the sensuous qualities of "secondary properties". [37] Owing to this abstract character, Berkeley points out that "matter" cannot be apprehended apart from the qualitative filling of sensation. For Berkeley, this both undermines the distinction between primary and secondary properties and calls into question the independent reality of such an abstraction as "matter". [38]

The abstract character of matter lends a certain ambiguity to Kant's treatment. He purports to go beyond what is in the *Critique of Pure Reason* by adding something that lies outside the general investigation of the knowing of any objects whatsoever. Here we are supposedly focusing upon a particular kind of object, namely corporeal things that fall within the domain of nature that does not include psychological phenomena and is accessed through "outer sense".

Although corporeal nature is presented as one particular sphere of objectivity, the Doctrine of Principles proves to be only applicable in full to objects of "outer sense". Moreover, Kant discounts the possibility of engaging in any kind of scientific investigation of psychology. [39] In discounting any psychological science, Kant is precluding not any empirical study that arrives at provisional generalizations based on induction, but any investigation aiming to come up with a priori laws of psychological phenomena. Why, for Kant, can there be no science proper of psychology? Why is the only real science of nature a science of material, corporeal nature ? A key reason, Kant points out, is that our inner experience consists of intuitions with no spatial, but only temporal connections. [40] That temporal succession of our inner intuitions is the only a priori element of inner experience. Everything else about them is contingent and arbitrary. Every phenomena of psychological experience will be temporally ordered, but the content of psychological appearances will be otherwise devoid of anything necessary and universal. Thus, if there were to be any science of psychology, it would have nothing to do but repeat the truism that all mental contents appear in a temporal continuum, and, if one were to draw from the

Anticipations of Perception, [41] acknowledge that all mental contents have some determinate intensity. Furthermore, it is unclear how the subject matter of psychology could be ascribed any objective character, since, as Kant emphasizes in the Analogies of Experience, the order of representations cannot have any objective character unless there is some abiding spatial backdrop, within which dynamic relations involving the locomotion of objects can be experienced. [42] Finally, Kant adds that psychological examination cannot avoid altering its object of investigation. Any observation of psychological phenomena involves intruding into one's own psyche and changing what is under view. Not only can one not observe the psyche of others directly, but introspection brings its own appearance into play instead of leaving intact the phenomena of inner sense. Self-examination is a psychological activity, so it automatically enters the field of psychological examination and transforms it. [43] Interestingly enough, Kant does not see any problem with an other form of self-examination, namely the critique of reason by reason. Somehow when reason examines itself it does not distort its object but is authoritatively and accurately self-transparent. Kant is oblivious to the objection that the scrutiny of reason by itself begs the question by assuming the authority of the reason whose validity is to be established.

Although Kant offers the above reasons for why the psyche cannot be scientifically investigated, he does not himself raise a more fundamental reason cutting to the core of the entire transcendental enterprise. Namely, the psyche cannot help but possess a spontaneity and self-activity that resists the pervasive external determination to which objectivity is necessarily subject as something determined by the structure of knowing. As determinative of knowable objectivity, the knowing subject must have a spontaneous, self-active character, whereas, objectivity, as determined by cognition, must be devoid of self-activity and governed by the law of efficient causality. On the basis of foundational epistemology , the only nature that can be known to be objective and which can offer an a priori element for genuine scientific apprehension is corporeal nature .

Furthermore, Kant points out, the science of nature can only address matter as such and take the form of a pure mechanics that investigates matter in motion. [44] All further phenomenal aspects of material nature fall outside scientific investigation proper. Chemistry, Kant notes, cannot provide any strict laws and count as a genuine science. [45] Chemistry addresses relationships between material objects in which they figure not as homogeneous matter, but as qualitatively different substances, as different chemicals. Chemical relationships operate in terms of the specific differences between types of materials, whereas mechanics deals with undifferentiated matter, to which physical law can apply its equal treatment. Why can there not be any necessary, universal laws pertaining to corporeal objects with respect to their qualitative diversity? The answer should by now be familiar. If knowable objectivity is determined by the structure of knowing, which determines all possible objects of experience, the only thing necessary will be what knowing puts in all objects without exception. Hence, objects of experience will be subject to an external necessity that applies to them no matter what they are. This necessity will therefore by a law of matter, which is indifferent to the qualitative distinctions otherwise differentiating material objects. Nothing pertaining to those qualitative physical distinctions will be knowable a priori or be susceptible of exhibiting anything universal or necessarily. Therefore it will be impossible to uncover any laws of chemistry, let alone any law pertaining to particular kinds of things. Instead, we foundational epistemologists (to think along with Kant) are strictly limited to restricting our scientific aspirations to the examination of matter in general.

To address the laws of matter, it is necessary to return to space and time . Kant presents us

with space and time in the *Critique of Pure Reason*, setting them before us in the same dogmatic way in which he presents the categories and the forms of judgment in his so-called "metaphysical deduction". Just as he offers us the categories and forms of judgment as factors found in the history of logic, so he points to space and time as inexplicable givens of human intuition. They are simply there as "facts" of consciousness in general that nonetheless underlie all experience and all knowledge of nature . Kant does not present space and time as having any necessary relationship to one another. He does not present one as in any respect dependent on the other. He just asserts that we happen to have them and there is no way we can possibly determine why we have them rather than any other forms of intuition. [46]

Kant has little more to say about time and space in their own right. Space has three dimensions, as in Euclidean geometry. Time has essentially one dimension, that arrow of time that moves from past to present to future. Kant identifies both space and time as intuitions rather than concepts because they both are totalities. Space is a totality insofar as all particular spaces are part of space, falling within the infinite expanse of space as a whole. Space is thus not like a universal that inheres in particulars that have other determinations not contained in the universal common to them. Space rather encompasses all particular spaces in their entirety unlike a concept that lies within particular instances of itself, instances which themselves encompass more than that concept. The same is true of time in its relation to particular moments of time . They are part of the totality of time , just as particular spaces fall within space as a whole. [47]

As forms of intuition, space and time have empirical reality and transcendental ideality. [48] Time orders inner experience without fail, just as time and space order outer experience without exception. All phenomena are therefore temporal, and all physical phenomena are spatial-temporal. On the other hand, their necessity extends only to appearances as they are given to our experience. This transcendental ideality is tied to Kant's claim that space and time are just accidents of what happen to be the structure of our sensibility. Since they are givens to which we can only point, Kant cannot say whether they have any intrinsic connection to one another.

Where then can Kant take us in the cognition of nature through reason, in the metaphysics of nature ? His aim is to provide for the kind of science that, as Foster points out, does engage in observation but no less involves an a priori element insofar as it establishes laws of corporeal nature that are universal and necessary. The treatise he offers, the *Metaphysical Foundations of Nature* , is divided into four sections, each of which supposedly applies the different types of categories exhibited in the types of judgments that organize our representations into experiences of objectivity. [49] What distinguishes these accounts from the corresponding sections of the Doctrine of Principles is that here the allegedly empirical element of matter is added. What is at stake, then, is seeing how matter gets determined with respect to the kind of categories that determine objects in general. Here we are going to witness how these categories specifically determine material, corporeal objects.

In the table of judgments from which Kant derives his table of categories in the *Critique of Pure Reason*, there is little account of how these forms are derived nor of whether they have any special ordering, where one would have to begin with one to get at another. Instead, the forms of judgment and the categories are both simply arranged in their stipulated totality, in groups of three under different headings or types. The only kind of connection that Kant draws regarding the categories is that within each type, the third of the three categories will combine the other two. [50] Otherwise there is no account whatsoever of their relationships.

By contrast, here in the *Metaphysical Foundations of Nature* the discussion of matter follows a definite order that seems to bear some connection to the successive contents under

examination. First, matter is considered with respect to its quantity. Second, matter is considered in respect to its quality. Thirdly, matter is considered in respect to its relations, and fourthly, matter is considered in respect to modality. We will find that what comes first needs to come first because it provides something that is an element of what follows and each successive section builds upon its predecessor.

In this first section, entitled “Phoronomy”, of the *Metaphysical Foundations of Nature* , matter is treated as nothing other than a pure quantum, without reference to any quality. Kant here analyzes the basic spatial-temporal determination of motion, abstracting from the quality of what is moving, including its particular mass or anything else that might pertain to it. In the following section, entitled, “Dynamics”, Kant conceives matter in respect to the categories of quality (reality, negation, and limitation), examining how matter moves in virtue of the quality of having moving force, which is shown to be part and parcel of the nature of matter. The account of “dynamics” depends upon first working out the more abstract “phoronomic” considerations of how motions relate to one another, irrespective of what is moving and what force is exerted. After this dynamic account of matter is explicated, Kant develops what he calls the “metaphysical foundations of mechanics”. Under this heading, matter in motion is conceived in regard to the categories of relation, in terms of which bodies are examined moving in respect to one another. This involves the familiar interactions of mechanics, where bodies collide and the motions following from their impacts are determined. Lastly, Kant presents “the metaphysical foundations of phenomenology”, under whose rubric the categories of modality are applied to material objects.

Most seminal in Kant’s discussion is the dynamic conception of matter that he develops following from the discussion of “phoronomy”. Kant gives matter an intrinsically dynamic character in order to distinguish matter from extension, as well as to distinguish matter from place , as Aristotle had conceived it. Lacking any such dynamic conception, Descartes , for one, identified matter with extension. [51] That identification precludes empty space, since space cannot be unoccupied by a body if extension is indistinguishable from matter. The conflation of matter and space introduces further perplexities. How, for example, can there be differences in density ? Empty space would allow for differing degrees of filling, according to how many and how large the gaps might be between different bodies or particles of matter. Without any vacuum or any dynamic conception of matter, how can bodies fill space with more or less intensity? Moreover, with matter identified with extension, motion gets reduced to vortexes, where bodies slip by one another without leaving any gaps. Then, however, how can different bodies be distinguished in the first place if no separation is ever possible?

Kant recognizes that solving these perplexities depends upon distinguishing matter from extension and that requires conceiving matter as dynamical. Matter can be more than mere space insofar as matter fills space by exerting a moving force impeding anything else from occupying its place . That exertion of moving force is essential to matter, for without it, matter evaporates into emptiness. In other words, matter must be a kind of force field, determinately occupying space by resisting the entrance of other equally exclusionary force fields. Before, however, any such dynamic account can be made sense of, motion itself must be understood. This requires comprehending how motion is determined in its own right irrespective of what is moving.

Admittedly motion is not included in space and time as these are determined as forms of pure intuition, rendering all possible objects of outer sense spatial-temporal. The metaphysics of material nature , which investigates the world of physical bodies, is accordingly not going to begin with an account of space and time in general. Instead, it must begin with matter as the

movable in space-time and conceive the purely spatial-temporal dimension of the movability of matter, leaving out of account everything else about bodies. Now if one is to think simply what holds a priori about motion, while abstracting entirely from everything else about what moves, the object of motion will figure in a completely elementary manner. That which moves will simply be considered as the occupant of a point in space-time , something with a location defined merely geometrically and temporally.

What lies at stake, to begin with, is just the motion of a point, which, as such, carries with it the changing relations of that point to other points in space-time , both moving or at rest with respect to it. Of concern is not the mass and force of bodies in motion, but the more elementary consideration of how motions combine into a single motion of a point or how the motion of a point can be equivalent to several motions. Kant thus begins with an investigation of composition in motion, taken abstractly.

There are really two sides to the account. One has to do with how the motion of a point is to be considered with regard to the space in which it is moving. Can we speak of the motion as proceeding in an absolute or a relative space? Is it absolute motion or relative motion ? The second point Kant addresses is whether we can say with any necessity whether multiple motions are combined in the motions of a point or, conversely, whether the motion of a point can just as well be equivalent to the convergence of separate motions. These considerations are needed to clarify the basic spatial-temporal parameters that then will be supplemented by considering what happens when these abstract trajectories are followed by material bodies that have the further qualitative character of wielding force. We will have to see how mass enters into any of this in an intelligible fashion. The phoronomy thus comes down to an examination of two questions. First, is space absolute or relative, rendering motion respectively absolute or relative? Second, how are motions combined into the motion of a point? That is really all that is at hand here.

In this connection Michael Friedman makes some interesting observations (in his introduction to the *Metaphysical Foundations of Natural Science*), drawing upon some of Kant's pre-critical writings on astronomy . [52] Kant there speculates about physical nature on an astronomical scale. He observes that we can regard the motions of our own solar system to be occurring within a galaxy , the Milky Way, which itself is part of a larger galaxy that could be one element contained within a still larger galaxy , itself encompassed within yet another, ad infinitum. Since there is no end to this series in the infinite expanse of space, the motions that we experience in our own solar system cannot be absolute. This is because our solar system is itself moving within a larger galaxy that is rotating as one of many other galaxies falling within a huge galactic array that is itself rotating, with no end to further encompassing intergalactic movements.

Here in the *Metaphysical Foundations of Nature* Kant has something similar to say. He argues on the one hand that it is impossible for us to experience anything other than space filled with material things, which he calls "material space". Material space, he observes, cannot help but be relative, which is to say that we can never experience anything other than relative space . Whatever motion we observe can always be considered to be taking place within a further frame of reference that is itself in motion against a back drop which is itself in motion, and so on. Hence we can never experience absolute motion or absolute space . [53] This claim will prove to be fundamental to Kant's consideration of motion and of action and reaction.

Kant's argument that space for us is material and that every material space has relationships that are relative might seem to have obvious implications for his central claim that matter is moveable rather than immovable. Does, however, the movability of matter follow from the

purely quantitative considerations of phoronomy or does it depend upon something more, something relative to the qualitative, dynamic character of matter? Aristotle had somewhat analogously insisted that motion was intrinsically bound up with material substance. What gives Kant the right to speak about matter being inherently moveable? Why can there not be matter that is immovable? The answer is not to be found in "phoronomy", but in the following consideration of the "dynamics" of matter. There, as we shall see, Kant will argue that matter as such involves moveable force and must therefore be moveable.

It is important to keep in mind that nature as an object of experience must be intuitable. To experience space and time we must encounter something involving the matter of sensation, with which the experience of matter is connected. Material space, space as it can be experienced, must therefore not be a totally empty space. A total void is unperceivable. Insofar as the continuity of time cannot be experienced without observing enduring spatial objects, as Kant argues in the "Refutation of Idealism" in the *Critique of Pure Reason*, [54] a totally empty space would render time unperceivable as well. As Kant there points out, the succession of our representations cannot enable us to be aware of the passage of time since each such representation gives way to another without any persisting remain. To experience time , we need to confront something that can stand as an abiding backdrop to the succession of our own representations.

Given that what alone can be perceived as spatial is material space, space occupied by bodies, given that any material backdrop can be found to be in motion against a further encompassing material space, and given that matter must be moveable, time will be experienced only in conjunction with the observation of bodies in motion, relative as that motion may be. Kant nonetheless notes that we cannot help but think about an absolute space as the ultimate encompassing universe in which all successive frames of reference fall . [55] We can think about it as an idea, but we cannot experience it. Rather, nature as we encounter it and as it stands as an object of science, will always involve motions that are relative. That relativity will be the key to thinking about how we can think of two motions being combined in a single motion. We can always combine multiple motions into a single motion by taking that single motion and adding or subtracting to it the relative motion of the space in which it is occurring. A moving point can be considered in motion against a backdrop at rest or equally against a backdrop that is moving. It all depends upon which frame of reference we focus upon.

Notes

1. Aristotle , *Physics*, Book II, Chap. 7, 198a25–28, in *The Complete Works of Aristotle* , I, p. 338.

2. Aristotle , *De Anima*, Book I, Chap. 1, 402a7, in *The Complete Works of Aristotle* , I, p. 641.

3. Aristotle , *Physics*, Book II, Chap. 7, 198a25–28, in *The Complete Works of Aristotle* , I, p. 338.

4. Aristotle , *Physics*, Book II, Chap. 8, 198b17–199a8, in *The Complete Works of Aristotle* , I, p. 339.

5. Aristotle , *Physics*, Book II, Chap. 8, 199a34–199b7, in *The Complete Works of Aristotle* , I, p. 340.

6. Aristotle , *Physics*, Book VII, Chap. 2, 243b10, in *The Complete Works of Aristotle* , I, p. 409.

7. Aristotle , *Physics*, Book IV, Chap. 1, 208a26–32, in *The Complete Works of Aristotle* , I, pp. 354–355.

8. Aristotle , *Physics*, Book IV, Chap. 4, 212a6–8, in *The Complete Works of Aristotle* , I, p. 360.

9. Aristotle , *Physics*, Book IV, Chap. 4, 212a6–8, in *The Complete Works of Aristotle* , I, p. 360.

10. Aristotle , *Physics*, Book IV, Chap. 1, 208b1–209a30, in *The Complete Works of Aristotle* , I, pp. 355–356.

11. Aristotle , *Physics*, Book IV, Chap. 1, 208b12–22, in *The Complete Works of Aristotle* , I, p. 355.

12. Aristotle , *Physics*, Book IV, Chap. 1, 208b9–12, in *The Complete Works of Aristotle* , I, p. 355.

13. Aristotle , *Physics*, Book IV, Chap. 1, 208b31–33, in *The Complete Works of Aristotle* , I, p. 355.

14. Aristotle , *Physics*, Book IV, Chap. 4, 211a12–16, in *The Complete Works of Aristotle* , I, p. 359.

15. Aristotle , *Physics*, Book IV, Chap. 4, 212a6–8, in *The Complete Works of Aristotle* , I, p. 360.

16. Aristotle , *Physics*, Book IV, Chap. 4, 212a8, in *The Complete Works of Aristotle* , I, p. 360.

17. Aristotle , *Physics*, Book IV, Chap. 10, 217b30–218a29, in *The Complete Works of Aristotle* , I, pp. 369–370.

18. Aristotle , *Physics*, Book IV, Chap. 10, 218b10–20, in *The Complete Works of Aristotle* , I, pp. 370–371.

19. Aristotle , *Physics*, Book IV, Chap. 10, 219b2–3, in *The Complete Works of Aristotle* , I, p. 372.

20. Aristotle , *Physics*, Book IV, Chap. 10, 219b1, in *The Complete Works of Aristotle* , I, p. 372.

21. Aristotle , *Physics*, Book IV, Chap. 10, 219b13, in *The Complete Works of Aristotle* , I, p. 372.

22. Aristotle , *Physics*, Book IV, Chap. 10, 219b15–29, in *The Complete Works of Aristotle* , I, p. 372. This line of thought becomes transformed through the lense of transcendental inquiry in Kant's argument in his "Refutation of Idealism" that awareness of the continuity of time depends upon perception of an enduring substrate connecting each moment, which, he maintains, can only be provided by consciousness of enduring spatial objects. See Kant, Immanuel , *Critique of Pure Reason*, trans. Paul Guyer and Allen W. Wood (Cambridge: Cambridge University Press, 1998), B275–276, p. 327.

23. Aristotle , *Physics*, Book IV, Chap. 10, 219b1, in *The Complete Works of Aristotle* , I, p. 372.

24. Aristotle , *Physics*, Book IV, Chap. 13, 222a30, in *The Complete Works of Aristotle* , I, p. 376.

25. Aristotle , *Physics*, Book IV, Chap. 14, 223b21, in *The Complete Works of Aristotle* , I, p. 378.

26. Aristotle , *Physics*, Book IV, Chap. 14, 223b22–24, in *The Complete Works of Aristotle* , I, p. 378.

27. Kant, *Critique of Pure Reason*, A127, p. 242; B162–165, pp. 263–264; A216/B263, p. 320.

28. Kant, *Critique of Pure Reason*, A148–235, B187–294; pp. 278–337.

29. Kant, *Critique of Pure Reason*, A84–130, pp. 219–244; B129–169, pp. 245–266.

30. Kant, *Critique of Pure Reason*, A80–81, B105–107, pp. 212–213.

31. Kant, *Critique of Pure Reason*, A82–83, B108–109, p. 214; A240–244, B300–302, pp. 357–358; A728–729, B756–757, p. 638.

32. Kant, *Critique of Pure Reason*, A22–23, B37, p. 157.

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39. Kant, *Metaphysical Foundations of Natural Science*, 471, p. 7.

40. Kant, *Metaphysical Foundations of Natural Science*, 471, p. 7.

41. Kant, *Critique of Pure Reason*, A167–176, B207–218, pp. 290–295.

42. Kant, *Critique of Pure Reason*, A176–181, B218–224, pp. 295–298.

43. Kant, *Metaphysical Foundations of Natural Science*, 471, p. 7.

44. Kant, *Metaphysical Foundations of Natural Science*, 476–477, p. 12.

45. Kant, *Metaphysical Foundations of Natural Science*, 471, p. 7.

46. Kant, *Critique of Pure Reason*, A27, B43, p. 177; A42–43, B59–60, p. 185.

47. Kant, *Critique of Pure Reason*, A25, B39, p. 158; A32, B47–48, pp. 162–162.

48. Kant, *Critique of Pure Reason*, A28, B44, p. 177; A35–36, B52, p. 181.

49. Kant, *Metaphysical Foundations of Natural Science*, 477, p. 12.

50. Kant, *Critique of Pure Reason*, B110, p. 215.

51. Descartes, *Principles of Philosophy*, Part Two, Sects. 4, 11, in *The Philosophical Writings of Descartes*, Volume I, trans. John Cottingham, Robert Stoothoff, Dugald Murdoch (New

York: Cambridge University Press, 1985), pp. 224, 227.

52. Kant, *Metaphysical Foundations of Natural Science*, pp. viii, xii–xiv.

53. Kant, *Metaphysical Foundations of Natural Science*, 481–482, pp. 16–17.

54. Kant, *Critique of Pure Reason*, B274–277, pp. 326–328.

55. Kant, *Metaphysical Foundations of Natural Science*, 482, p. 17.

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4. Space-Time and Matter

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Kant's dynamic account of matter relies upon the combination of attraction and repulsion to fill space in a determinate way. Matter cannot be distinct from empty space, Kant insists, without involving both of these complementary moving forces. [1] Attraction by itself collapses into a point, whereas repulsion on its own disperses to infinity. Only both together can provide for an occupation of space distinct from the void . Moreover, the quantity of matter, as opposed to the volume of extension, is determined by nothing but the magnitude of these forces, which accounts for the amount of matter in a determinate space or location. [2]

Does Kant's explanation adequately provide us with the basic stuff we need to proceed with further conceiving nature ? How are we to make sense of moving force in general and how can the two complementary forces of attraction and repulsion be constitutive of matter? Does Kant's account of attraction and repulsion presuppose a plurality of bodies attracting and repelling one another, thereby begging the question by assuming what is to be explained? And how can opposing attractive and repulsive forces not only materially fill space, but provide matter with a magnitude, a determinate mass ?

In considering these questions, we must confront the daunting fact that Kant vacillates between characterizing repulsion and attraction as constitutive of matter and characterizing them as forces exerted by existing bodies upon one another. [3] There is a fundamental difference between conceiving attraction and repulsion as forces wielded by preexisting bodies and thinking of them as constitutive of matter in the first place . Hegel maintains that Kant's dynamic account of matter systematically confuses these two characterizations [4] and we must investigate to what degree this is true and how, if so, the problem can be remedied.

To accomplish this, it is important to revisit the factors on which the dynamic account of matter depends. Hegel's conception of space, time , and place provides a crucial resource for unraveling what lies at stake. Hegel successively develops these elementary aspects of nature as preceding the constitution of matter both in thought and in reality. Their priority does not signify a temporal succession. After all, the proposed emergence of time from space can hardly occur in time . Rather, their ordering is that of the natural presuppositions without which matter cannot be or be thought.

4.1 Hegel's Account of the Emergence of Matter from Space, Time , and Place

The distinctive break through of Hegel's insights can best be seen in contrast to what little Aristotle has to say about matter and what Kant offers in his dynamic account. Unlike Hegel, Aristotle and Kant both begin their theories of nature by according matter, and, more specifically, material substance, a foundational character, presenting matter as at hand from the very outset, letting it serve as the basis on which everything else in nature is to be determined. Insofar as Aristotle 's ontology roots being in substance, his philosophy of nature , that is, his *Physics*, sets natural, material substance, as the bedrock of all natural relations and qualities. For Aristotle , what distinguishes natural substance from other substances is that natural substance is always subject to motion. Although motion here signifies change in general, Aristotle maintains that locomotion is at the root of all other types of motion or change, either accompanying them or comprising the enabling, but not determining condition of the other forms of change.

The distinction between enabling and determining conditions is an important difference that will figure prominently in the fabric of natural processes. An enabling condition allows something to occur without determining what occurs. An enabling condition permits something to happen, but the specific way it occurs is left open by the enabling condition. The enabling condition thus allows for a range of possibilities, all of which it facilitates without fully determining the outcome. Some further principle of determination must be relied upon to completely specify that which the enabling condition permits to occur. In this respect, locomotion will allow other changes to happen, whose specific character is determined by some further cause, be it formal and/or final. Accordingly, Aristotle will bring in spatial and temporal determinations from the very outset, but these will be given in respect to material substance, which is further determined by its specific nature . Hence, from the start space gets defined as place and time gets defined as the measure of the change of place of material things in motion.

Kant, on the other hand, begins his account in the *Metaphysical Foundations of Natural Science* by applying to material substance the different categories that necessarily determine objects in general as they can be given to us in experience. Although the categories are not presented in any necessary generative order in the *Critique of Pure Reason*, their application to material objects in the *Metaphysical Foundations of Nature* does seem to have a structural order.

The opening "phoronomy" section, which determines material objects with respect to quantity, necessarily precedes the discussion of dynamics. This is because the dynamical determination of material objects presupposes the abstract relations of points in motion, without which matter could not be considered as moveable and moving force could not be thought or experienced. Nonetheless, Kant does not account for space and time per se. He begins instead with reference to matter as moveable and we will want to ask ourselves what grounds if any Kant has for this assumption.

Hegel clearly attempts to do something with which neither Aristotle nor Kant really come to grips: to account for what can be regarded as the minimal specification of nature . That minimal determination of nature takes no other natural specifications for granted and, in so doing, takes for granted nothing other than logic or determinacy in general. In contrast to logical determinacy, natural determinacy has the minimal further qualification that makes it other than mere thought. The question that Hegel does not shirk from addressing is what is that minimal threshold that can

be the first determination of what is natural, the specification that takes for granted no other real, non-logical determinacy and thereby can be that on which all other natural specifications rest. Every further determination of nature will rest upon this minimal starting point in either containing this minimal determination or being predicated upon it.

Hegel begins the philosophy of nature with space and this point of departure sets him apart from both Aristotle and Kant. Unlike them, Hegel does not begin with moving or moveable material substances, for he recognizes that moving bodies already involve space and time and place and matter in general. To begin with material substance would therefore involve presupposing the more rudimentary factors of nature and preclude establishing what these are. The same dogmatic incoherence is at hand if space and time are considered from the outset to involve material substances. That involves going around in circles, defining space and time in terms of the more concrete natural factors that take spatiotemporal order for granted. It leaves the philosophy of nature powerless to determine coherently how place and matter are themselves constituted. If we are to make any claims about what is moveable or in motion in nature , we must take for granted space and time .

Kant might be said to have dealt with space and time prior to his account of matter as moveable in that the *Critique of Pure Reason* already argues that space and time are forms of our sensible intuition. Kant, however, there admits that beyond identifying space and time as forms of sensible intuition, we can say nothing more about why they are. We just find them as facts of human cognition, for which further explanation is lacking. They are simply given to us as forms of our sensibility. They have no intrinsic relation to one another, nor can it be said that one depends upon the other. Thus, it makes little difference whether the account of one precedes the other. They are simply described side by side.

Hegel obviously has a very different treatment to offer. To begin with, Hegel regards space as the first factor of nature . Space is more minimal than time , for space presupposes no other natural specification, whereas time does. As Hegel will show, time depends upon space, whereas space has its rudimentary determination independently of time .

How is this so? Space, Hegel maintains in paragraph 254 of his *Philosophy of Nature* , is the “first or immediate determination of Nature ”. [5] Whereas space is unmediated by any other natural determination, every other natural specification, including time and matter, involves space. As immediate, space cannot be characterized in terms of motion, which of course incorporates space as well as time by involving change of location over time . Space as such cannot be defined in regard to matter or to anything else in nature . As Hegel notes, space is that which is natural yet immaterial. Space is not just a category or a logical determination, but it is not material either. Space has no sensuous character, yet it is not merely a thought. [6]

The immateriality of space is crucial for any theory of matter. The great challenge in conceiving matter is that matter cannot be accounted for or constructed out of anything that is itself material. If one does employ anything material in the determination of matter one just runs around in circles, taking for granted what is in need of an account. Somehow, matter must be specifiable using completely immaterial resources. Hegel’s determination of space provides the first pillar for the immaterial account of matter and, as we shall see, Hegel is intent on providing such an account by specifying matter in terms of space and time . In so doing, he does not revert to the empty identification of extension and matter, with which Descartes hobbled his theory of nature . Instead, Hegel will show how relations of space and time provide for something material that is irreducible to either. How this can be is what now must be confronted.

To begin with we have space and space has a very minimal determinacy. Hegel speaks of

space as a totality very much as Kant describes space in the *Critique of Pure Reason*. Kant identified both space and time as pure intuitions rather than concepts because they are totalities in the sense of containing within themselves all particular spaces and times respectively. Concepts, for Kant, inhere in particulars that have other distinguishing features not contained in the inhering concept, for otherwise nothing would differentiate the particulars from what they hold in common. By contrast, space and time completely contain all places and moments within their respective wholes. [7] Although Hegel, in his philosophy of mind , will grant that space and time figure psychologically as forms of sensible intuition, he avoids Kant's subjective idealism by addressing space and time in their own right as elementary factors of nature . Space and time are indeed formal, but not just by being forms of intuition. Intuition may well involve spatial and temporal orderings of the contents of sensations, but space and time are themselves elementary, immaterial determinations of nature , within which mind itself has its reality as a worldly, embodied self that is not merely reducible to something purely physiological.

Space is a totality, encompassing all of its particular instances completely within itself, but it is a wholly abstract totality. Space has the character of being external to itself. This self-externality has a logical character that must be defined without invoking spatial relations. Space is self-external in that it renders itself other to itself, but not to anything else, since every other factor falls within its bounds. Space falls apart from itself, ever extending beyond itself in an unbroken continuity. Space has this uninterrupted continuity because there is nothing about the way that space is external to itself that involves any kind of qualitative, real differences. Each part of space as such is indistinguishable from every other, even though they fall asunder. Every aspect of space always has more of itself outside itself. [8]

The most minimal distinction of space is a point. It comprises the most elementary non-space or negation of space. All by itself the point exhibits the same kind of self-externality that applies to everything spatial. A point cannot help but have other points adjacent to it. Every point is thereby immediately other to itself, terminating in another negation of space that is indistinguishable from itself. Each point has another lying immediately beyond itself, without any intervening gap. Since every point has another in continuity with itself, the point cannot help but form a line, consisting of the continuous self-externality of otherwise indistinguishable points. [9]

A line, however, cannot help but be self-external as well, for at its edge there cannot fail to be another line, which has another line beside it involving the same self-externality. Consequently, just as the point cannot escape generating the line, the line cannot help but generate a plane. The plane, of course, has another adjacent to it, generating a seamless series of planes comprising a volume of three dimensional space. If that volume is in any way limited, it too cannot help but have other volumes extending beyond itself without end. In each case, the successive aspects of space have beyond them something that is other from them, but equally no different, generating the ever extending continuity of the totality of space. In this way, space, as self-external, comprises a totality, in continuity with its own "negations" or externalities. [10]

What does this continuous totality signify for determinate spatial locations or places? What can "here" be as opposed to "there"? Here is immediately different from there, but how can they be distinguished? What is there is not here, but what is not here is also a "here", different from other "here's" or "there's". By itself, space provides nothing that allows one to distinguish one "here" from another. Every location is equally "here" and "there" in respect to other "there's" and "here's."

This convergence of the difference and identity of every abstract spatial location is what

leads Hegel to speak of space being in itself absolute, rather than relative. In the addition or *Zusatz* to paragraph 254 of the *Philosophy of Nature* , Hegel observes that absolute space is "only the abstraction of space". [11] Relative space is a more concrete spatial determination, in which distinguishable frameworks of moving objects stand in relation to one another. These involve further specifications that are not provided by the mere self-externality of space and its generation of extension. Space by itself, without yet involving time , let alone motion and matter, cannot be anything other than absolute because it lacks any concrete filling that could provide for the contrast of different determinate spatial contexts, such as "inertial frames of reference" or material "Gaussian co-ordinate systems". [12]

The absolute character of formal space is very different from what Aristotle affirmed to be the absolute nature of place . Aristotle recognized that, abstractly considered, right and left could be considered relative, since if one changed one's vantage point, what was right could become left and vice versa. Yet, if one considers what is up and down, Aristotle maintains that one encounters an absolute spatial distinction. This difference is rooted in natural place , which is tied to the specific nature of material substances. [13] Reference to the unmoved mover may give no more absolute direction than the eternal orbit of celestial motion. The active form of natural things, however, directs them to a specific place , whose location is thereby absolutely grounded in the causal principle of nature . What is earth tends to move down in an absolute sense, just as what is fire tends to move up in an absolute sense. These are not relative directions because they are tied to the unequivocal place to which things of a certain kind gravitate. Without that connection, Aristotle recognizes, there would be no way to distinguish one direction from another in any unqualified, absolute manner.

Kant removes all such connection by understanding natural necessity to be restricted to material laws indifferent to the specific form of things. Insofar as Kant conceives the space of nature with reference to moveable bodies, it should be no surprise that for Kant space is relative, together with the motion that proceeds within it.

Typically, talk of the relativity of space invokes inertial frames of reference, where spatial relations refer to the motion of a body in relation to some physical background involving moveable and/or moving bodies of its own. In this concrete framework of a plurality of bodies in motion relative to one another, it is arbitrary which frame of reference is regarded as stationary. There appears to be no objective way of determining whether any particular body is in motion or whether its background is moving in the opposite direction while it remains stationary. Both scenarios seem equivalent, just as do all the numberless intermediate schemes in which the bodies move in opposite directions at various speeds and accelerations, while retaining the same difference in speed.

Although Hegel is well aware of this relativity of spatial relationships in the concrete setting of bodies in motion, he still insists that space per se is absolute. Space, without further qualification, that is, space, still unqualified by time , matter, and motion, allows for no relativity since it lacks what is necessary for there to be determinate spatial frames of reference. The self-externality of space that generates lines from points, planes from lines, and volumes from planes has nothing to which it can be relative. Space, by itself, provides no basis for establishing any determinate differences that allow for distinct spatial frameworks.

Instead, Hegel shows us, space gives rise to time . What is ground breaking in Hegel's account of the transition from space to time is the twofold insight that time presupposes space and that space cannot help but give itself up to time . There cannot be time apart from space and space cannot fail to engender time . No *Deus ex machina* need be invoked to account for the

space-time continuum. Nature can have no more indeterminate, rudimentary factor than space and space is sufficient to provide for the emergence of time .

What then is the basic, minimal determination of time ? Must it be characterized in respect to space? Hegel maintains in the addition to paragraph 257 of the *Philosophy of Nature* that time is what space becomes. [14] How does space become time and how can time be thought of in terms of space?

Is every step in the development of space from point to line to plane to volume a moment in time ? Certainly, the development in question is not just a logical succession of categories of thought. Point, line, plane, and volume are real spatial determinations. They are non-logical, even though they are immaterial. Is their "succession" a passage in time and thereby a generation of time ? In each case, the "move" from one spatial determinacy to another is immediate, without any intervening intermediary stage. Furthermore, there is no separate abiding backdrop against which these developments proceed. They comprise differentiations of and within the totality of space by which its self-externality unfolds. They are merely spatial differences without any temporal distinction. The continuity of points, lines, and planes is a continuity of spatial distinctions and not of moments in time . Something more must be supplied to provide for any differences that can count as temporal.

For there to be any time , non-logical differences must no longer simply fall within space as negations internal to its self-externality. Instead, time , as non-spatial, must involve a negation or becoming other to spatial determinacy as a whole. Hegel gives us the elementary solution to this challenge: time is the totality of space being external to itself. Instead of setting a part of space, such as a point, a line, a plane, or a determinate volume external to some other spatial factor, time sets space other to or "outside" itself in its entirety. How can space be self-external in its totality? By being space *now*, which becomes other to space *before*. The succession of time is none other than the continuous othering of the totality of space, whereby space is external to itself as a whole. Each moment in time is the totality of space as supplanting its own totality and immediately giving way to its own totality once more and so on.

Whereas space was external to itself in a spatial manner in the development from point to line to plane to volume, the self-externality of space in its totality involves a development that can no longer be spatial in character. The self-externality basic to space pushes space beyond itself, for once space has exhausted the intra-spatial options provided by the negations of point, line, plane, and volume, the defining character of space pushes it beyond itself, a beyond that consists in nothing more than the continuous self-externalization of space in its entirety. This involves no other resources than space itself provides and it is generated by nothing other than the self-externality intrinsic to space.

The totality of space can be outside itself only from one moment to the next. The passage of time is nothing but the ongoing differentiation of space in its totality. Here the totality of space is negated. Time is that in which space becomes its own non-being. The now is immediately space that is no longer, that has passed into the past. Now is that which the future will be in that the now becomes the past, making the future present. There is no other resource available for distinguishing the past from the present other than the totality of space being external to itself. Any other natural factor presupposes space and time and therefore cannot be employed in constituting time . Time is the self-externality of space as a whole, where space is continually set in an external relationship to itself. The present, past, and future cannot be distinguished by anything other than the non-being of the totality of space that is just as much the totality of space as external to itself. The present is immediately past and the future is immediately present insofar

as space as a whole is self-external and this self-externality is time . These distinctions of the ever succeeding “otherings” or self-negations of the totality of space are just as equivalent as the differences in space itself. Just as every point, line, and plane is identical in character to every other, so there is no way of distinguishing any “now” from any other “now” in terms of time itself. [15] Every “now” emerges from the past and is pregnant with the future. The spatial totality that has replaced what has slipped into the past is no different from its predecessor or successor. Only more concrete determinations of nature , involving bodies in motion, can provide for any real contrasts, but matter and motion themselves presuppose space and time and their seamless continuities.

In and of themselves, the temporally distinguished totalities of space contain nothing that can concretely distinguish them from one another. Each moment of time , each distinction of past, present, and future, presents the same self-external spatial totality. The “now” is space that is other than space that was and space that will be, but that otherness is completely devoid of any further content. This difference that is no difference is what allows Kant to call the “now” the same thing as eternity. The “now” may instantaneously slip into the past, but another “now”, no different from it, just as instantaneously replaces it, to be instantaneously replaced by another “now” without end. The very character of the “now” is such that it keeps on returning to itself in slipping into the past and giving way to the future.

The resulting continuity of time has a completely abstract determination, yet it is more concrete than that of space precisely because the flow of time contains space in its totality with a further qualification. That qualification is that time encompasses space together with the process by which the totality of space becomes external to itself, taking on the additional character of being “now”, straddling past and future. The totality of space has become poised between these temporal dimensions, into which it is ceaselessly drawn, continually reverting to the same timely situation. As Hegel points out, the dimensions of time are just as abstract as the dimensions of space. [16] Just as depth, height, and width have no abiding difference, so every moment of time is just as much present, past, and future. The past was the future and the present, the future became present only to fall into the past, and the present becomes past and takes on the future. Like the dimensions of space, so the dimensions of time end up having equivalent specifications.

Space and time have hereby shown themselves to have an intrinsic relationship to one another. Space is the minimal threshold of what can be considered natural and space cannot help but give rise to time , which incorporates space within its process. The emergence of time from space is clearly not a temporal event, since there is no time before time . There cannot be a time when there was space without time . Once, however, time emerges and encompasses space in temporality, space is in a position to become more concretely determined. Namely, with space and time at hand, place can both be and be conceived.

Hegel shows how this is so by outlining how place issues from a unity of space and time . Once there is time setting the totality of space external to itself, the completely abstract spatial location of a point can take on a more determinate character, making possible the distinguishing of place . What is the concrete character that Hegel sees fit to identify with place ? He will not characterize place by making reference to matter. Matter cannot be invoked, for matter itself will incorporate place in its own constitution. What then can place be, if all it involves is space and time ?

Is motion to be introduced to determine space and time as place , or must motion, like matter, presuppose place ? Aristotle seems to characterize place in reference to natural substances and the motion to which they tend by nature . The primary motion comprising locomotion , however,

is change of place . So motion takes place for granted and place must therefore be determinable prior to locomotion and moving substance.

With motion and matter excluded from the determination of place , one is tempted to think of place as something merely spatial in character. Place , however, is not just “here”. “Here” is assignable to every point without exception, but place is a determinate location. What then, can space and time offer that allows place to be more determinate than “here”? The answer is simple and rudimentary: thanks to time and its encompassing of space, place can be both here *and* now. Place combines space and time . It is spatiotemporal location. Place is a “here” that is mediated by time and a “now” that is mediated by space. Place is still relatively abstract, but it is more concrete than either “here” or “now” in virtue of nothing other than uniting them both.

By itself, “here” has no temporal determination. Time , however, does encompass space. Nonetheless, the present, like the past and future, involves reference to only the totality of space, not to any particular here. “Now” thus has no specific spatial connection. Place provides the elementary juncture of space and time , of “here” and “now”, doing so in virtue of nothing but what is contained in the ongoing process of space-time .

Motion obviously depends upon place , just as does matter if matter requires a dynamic account involving moving forces. Motion, understood as locomotion , involves change of place , that is, a change of spatiotemporal location from one “here” and “now” to another “here” and “now”. As Hegel puts it, motion involves the succession of time exhibiting itself in spatial determinations and the change of location exhibiting itself in the passage of time . [17]

From where does this dual process of motion arise? The bare process in question is formal, since it does not involve matter and any of the real differentiations of place that material bodies in motion provide. It is what Kant addresses in his discussion of “Phoronomy”. What leads place to generate motion is the same self-externality that leads points to generate lines, lines to generate planes, planes to generate volumes, and spatial totality to generate time . Since each “here” and “now” is indistinguishable from every other in a seamless continuity, the same continuity applies to each space-time unity. Each place is in continuity with others, since none retains any abiding distinction from what it has outside and before and after itself. The self-externality of place is motion, the transition of each particular place into others separated yet adjacent in both space and time .

What must be added to formal motion to provide for matter? Two deficits must be overcome. First of all, if something occupied just a point in space time , would there be any way of distinguishing between its presence and its absence? The infinitesmal spatial punctuality of a point precludes any material actuality that could hold itself apart from the void . Likewise, if something were just now, at hand for a mere moment of time , would there be any way of distinguishing between its presence and its absence? Any material actuality would be instantaneously cancelled as the present moment immediately passes away. These considerations indicate that for anything material to be, it must both endure and occupy a determinate volume. Matter must have an extended as well as a persisting presence. Any actual body must occupy a bounded volume and endure for some time . Otherwise, there is nothing material.

This gives us a foretaste of what the minimal specification of matter must involve. Matter will combine space and time , comprising a here that is now and a now that is here. Yet, matter must be more than the here and now of place or the formal motion of points in space-time . Matter must lay hold of some extended space over time and do so in a way that distinguishes its enduring occupancy from that of empty space-time .

By itself, place offers nothing to prevent one place from passing over into another. What is

other to place is merely a “not-here-and-now”, which cannot hold itself apart from any other “not-here-and-now”. Every not-now is another now, just as every not-here is another here. Every not-here-now is a here-now, every other place is a place as well. Hence, there is no way of preventing place from becoming other than it is. As Hegel suggests, place cannot help being identical with other places. [18] Place becomes other places and in so doing, place gives rise to motion in a completely formal way. The motion is completely formal because all it comprises is how the passage of time becomes a change of place and alternately how change in place becomes a change through time . Kant develops this formal motion in the “Phoronomy” section of his *Metaphysical Foundations of Natural Science*, as if it somehow applied to matter as moveable, with abstraction made of every material feature except for quantity, thinking of matter just as a point moving through space.

Kant presents the formal account of matter as paving the way for the dynamic constitution of matter . Hegel follows suit at least to the degree that he presents the formal specification of motion as giving rise to the minimal specification of matter. Matter will once more be intrinsically connected to motion. On this basis, Hegel is going to renew aspects of the dynamic discussion that Kant forges, but do it in an importantly different way.

4.2 Problems Arising in Aristotle ’s Conception of Matter

Before addressing how the dynamic constitution of matter proceeds, following from Hegel’s critical revision of Kant’s account, let us look back briefly at what Aristotle has to say about matter and indicate the difficulties his conception entails.

What can be said about matter in the philosophy of nature that Aristotle pioneers, where substance is ultimate and nature is governed by a first principle of active form? There is not too much to be told about matter in Aristotelian nature .

To begin with, matter has a metaphysical specification, concerning what pertains to substance in general, irrespective of whether substance be natural or not. This specification does not determine matter as a kind of substratum, in which qualities inhere. Such a substratum is what early modern philosophy tends to identify with substance—a subject that takes on properties of one sort or another, by which family resemblances with other things are established. Matter, for Aristotle , is instead a pure potentiality to take on form, whereas substance combines both matter and form.

Matter as such does not have any determinate tendencies or any specific properties besides being pure potentiality. There cannot be any laws of matter. Only when matter takes on form does it become actual and acquire any further determination. Since forms are specific, there are no formal determinations that apply to all matter in the way that law applies equally to everything in its jurisdiction. [19]

Moreover, as Aristotle points out in his *Physics*, matter cannot come into being or pass away. [20] Since matter has no determinate being of its own, what can cease or come into being is the presence in matter of some form. Accordingly, what occur in nature are changes in substance, where matter takes on different forms. None of these changes alters matter’s identity as pure potentiality.

Matter is always susceptible of losing its current form and obtaining another, although the actuality it possesses in virtue of its form determines its further malleability. Matter, as formless, is not subject to change as matter, however, and this signifies that matter cannot move itself in any respect. Matter will not exert any moving force, such as gravity , nor will matter possess inertia , maintaining whatever motion it undergoes. Matter will just be pure potentiality and whatever actuality it obtains will derive its specific determinacy from the form imposed upon it. Matter that has the form of earth will move downward because of its earthly form, not because matter as such exerts gravity and is subject to gravitational attraction. If matter were to move itself in any manner, it would not be pure potential, but a specific actuality with some determinate tendency to movement.

Does matter become something more determinate when we leave metaphysics behind and enter the particular region of being of nature ? Can *Physics* say anything specifically about the matter that belongs to what is natural? Natural matter may share the basic character of matter in general, but what distinguishes it as a particular species of matter?

Aristotle has distinguished natural from non-natural substance. Natural substances move themselves, whereas non-natural substances, such as artifacts, [21] do not. Natural substances contain a principle of change within themselves. They have an active form, like a soul, whereas artifacts have a passive form that must be imposed upon the matter that embodies it by an act of craft, whose making, or *poeisis*, extinguishes itself with the production of the artifact . Admittedly, the matter of an artifact is already a natural *substance*, such as earth or wood, which

is not just matter, but “ensouled” matter, with its own inherent tendencies to move in a certain way.

Given this difference between natural substance and artifacts, does natural matter have any specific character of its own? What does the active form of natural substance imply, if anything, about natural matter?

It will not imply that there are laws of matter. Laws of matter would hold true of all natural substances, irrespective of their specific form. Natural substance, however, undergoes alterations in virtue of its active form, which is common to not all matter, but only those materials that share that specific form. For this reason, there is little room for natural matter to have any general properties that distinguish it from matter in general. Not only will natural matter have no lawful character, but it will not possess any forces as such.

Aristotle does, however, suggest that natural matter has a special relation to form, exhibited by the oft repeated example of Socrates ’ snub nose, which significantly refers to a living being. [22] The form of “snubness” is allegedly intrinsic to noses, for it is a form that does not apply to anything else. On this model, natural matter will be “proximate” to the active form with which it is associated. In other words, natural matter will not just be pure potential, but a determinate potential, specially linked to the specific actualization realized by the active form in question. Accordingly, matter in nature is always going to be a proximate matter in the sense that it has to be able to undergo the motion specific to the type of substance to which it belongs. Although natural matter will thereby have a specific potential, instead of a pure indeterminate potential, it will not exhibit that particular potential unless it is enlivened by the corresponding active form. To cite one of Aristotle ’s favorite examples, which again tellingly involves an animal organism , a hand that is cut off loses its animating principle and changes materially. As dead flesh, the erstwhile hand no longer possesses the specific potential it formerly had. It may become reduced to earth and water, but never does it become subject to laws or forces of matter per se. Instead, as earth, the matter will have certain properties of motion that are distinct from those of the matter of water or the matter of fire.

Does the Aristotelian account of matter in nature make sense? Does natural proximate matter, enlivened by active form, exhibit a specifically biological character that does not apply to matter in nature in general? Moreover, does the self-moving natural substance containing such matter itself depend upon inanimate matter, governed by law and endowed with both inertia and gravity ?

4.3 Kant's Dynamic Account of Matter

A first step towards resolving these questions lies in grappling with Kant's dynamic account of matter.

To begin with, we need to reflect on the task of the "Metaphysical Foundations of Dynamics" that forms the second of the four parts of Kant's *Metaphysical Foundations of Natural Science*. As we have seen, Kant characterizes each of these four sections as determining matter with respect to a different category. [23] Here, in the dynamic account of matter, matter is allegedly being developed in terms of the category of quality. By contrast, the prior "Phoronomy" section addressed matter in a purely quantitative way, which ultimately meant treating matter merely as a point with regard to its motion. In dynamics, Kant is dealing with matter in terms of a qualitative determination, where some essential property of matter is identified that distinguishes it from what is not material. Here, matter is to be addressed as moveable insofar as it fills a space. Moving bodies are no longer to be considered solely "quantitatively", as spatial points in motion. Now what lies at stake is accounting for the minimal being of the moving body as matter. In this regard, we will be confronting the factor that will distinguish "real" from merely "formal" motion, as well as "real", material from merely "formal", immaterial space. To conceive the real in space and time requires uncovering the natural features that allow for space and time to have a determinate actuality.

It is no accident that Kant addresses phoronomy before the dynamics of pure mechanics . The dynamic account of matter can only determine how matter fills space after and on the basis of the account of phoronomy because dynamics employs the formal determinations of motion. Dynamics does so because matter dynamically fills space by comprising a moving force, which, as moving, incorporates the formal properties of motion. Phoronomy is thus presupposed by dynamics.

On the other hand, the dynamic account of matter serves as a presupposition of mechanics. Mechanics requires that dynamics already be at hand because mechanical relations between bodies take for granted the dynamic filling of space that first makes bodies possible. Mechanics, in Kant's formulation, determines matter in respect to the category of relation [24] since it concerns how bodies relate to one another in respect to force, mass , and motion.

Kant brings into play a plurality of forces, distinguishing attraction and repulsion in the constitution of matter and adding gravity in respect to the relation of bodies to one another. Gravity is linked to attraction and we will have to see to what extent the attractive force constitutive of matter is equivalent to gravity . These forces might be regarded as the properties inherent in matter. When, however, we consider mechanics with its relations of bodies, what constitutes individual matters must already be present in nature and in thought. Mechanics presupposes dynamics because dynamics establishes what it takes for there to be matter in the first place .

Dynamics does not just address matter in general. It is equally concerned with accounting for individual matter or what is involved in there being determinate bodies. How can there be something material rather than the formal nothingness of empty space-time ? Dynamics will provide the answer. We will see how matter in general is such that matter cannot help but entail a plurality of matters, of individual bodies. What is constitutive of matter constitutes matter in such a way that matter is necessarily individual, that matter necessarily exists as an individual material thing occupying a determinate place distinct from that of other bodies.

Why is matter such that it necessarily involves relations between bodies, in which mechanics can enter? Why can undifferentiated matter not just flood the whole universe, encompassing all space in one big blob of matter? The key reason lies in how matter can only be distinguished from empty space if it determinately combines forces of attraction and repulsion, without which it dissipates to infinity, leaving nothing different from an infinite void .

Matter as such will automatically individuate itself because of how it is constituted. Matter cannot help but be as a body filling a determinate volume in a determinate place subject to a determinate trajectory of motion. Nothing about matter will enable a single body to be the one and only body . Repulsion and attraction may originally fill space without involving individual bodies repelling or attracting one another. Still, in order to have *moving* force, either as elastically resisting or gravitationally attracting, matter as body will entail a plurality of bodies, each already constituted by internal attraction and repulsion. What constitutes matter as an individual body , however, will leave open, at least to begin with, how many bodies populate the universe, where they are located, and how they are each moving.

To think about matter in general is something very different from thinking about an individual body . An individual matter as particular requires being in relation to other matters from which it is distinguished. Matter as an individual body is accordingly embedded in all sorts of material relationships. Matter as such, by contrast, is that which is common to all individual bodies.

This difference might seem to be at play in how Kant's account of the dynamics of matter falls in between the abstract account of motion in "Phoronomy" and the account of mechanics. Mechanics presupposes a plurality of bodies whose materiality has already been constituted, enabling bodies to enter into relation with one another. Dynamics thereby provides what applies necessarily and universally to all bodies as such, independently of their mechanical interaction. The general task addressed by dynamics is to account for matter as something real in nature . Matter must be determined to be not just a point at rest or in motion, but something that has a real presence in space-time , possessing extension for an enduring time . The daunting challenge in accounting for matter is how to constitute material being without employing any factors that already involve matter or a plurality of bodies. To use any material resources would beg the question. For example, one cannot account for matter by appealing to any material particles. Doing so would amount to assuming what one is trying to establish. Somehow, matter must be constituted solely out of *immaterial* factors.

How then can matter be constituted out of nothing material? Kant offers us a first attempt at a solution by drawing upon the formal determination of motion in space-time . In considering Kant's solution, one must keep in mind that his whole discussion is predicated upon a foundational epistemology that is trying to understand how the object of knowledge is determined by the structure of knowing. *The Critique of Pure Reason* has already mandated that objects of experience will have certain general determinations due to the forms of human sensibility and the forms of judgment given expression in the categories. On Kant's account, we already know that the appearances by which we experience objects are going to have extensive and intensive magnitudes. We also know that knowable objects are determined as substances, as the First Analogy dictates, and that all alterations in experience are going to be changes of substances determined by antecedent state of affairs through efficient causality, rather than formal or teleological causality. Moreover, we know that coexisting objects of experience will necessarily be subject to reciprocal causality, making manifest their coexistence through the perceivable marks of mutual influence. All of these principles of experience are laid out in the

Critique of Pure Reason, but allegedly without explicitly referring to anything material. In the second edition of the *Critique* Kant does add certain qualifications, suggesting that his principles of experience apply exclusively to material objects of outer sense. [25] Nonetheless, Kant maintains in his *Metaphysical Foundations of Natural Science* that the application of the categories to material objects depends upon the empirical factor of tactile sensation, which can only be taken into account in this sequel to the *Critique*. [26]

The account of matter that Kant now undertakes in the *Metaphysical Foundations of Natural Science* significantly clarifies the principles of experience that are advanced in the *Critique of Pure Reason*. In particular, the principles of causality and reciprocal influence, as presented in the *Critique*, can appear quite mysterious on their own. Causality has to be determined in such a way that it completely abstracts from everything material in the sense in which the "matter" of sensation figures in experience. That "matter" concerns everything that is not formal about the relationships of objects, that does not just involve position in space and time . This whole material side of sensible intuition is, on Kant's account, wholly contingent and empirical. It is completely devoid of any necessity and of any universality. The principles necessarily and universally determining objects of experience exclusively pertain to the spatiotemporal determinations of objects. Somehow, causality and mutual influence must be exhibited in those terms alone. That is why Kant will insist that we can only find causality and reciprocal causation manifest in outer experience. All that can properly exhibit these causal relations is the motion of matter and its display of moving force. Nothing in inner experience is sufficient to manifest efficient causality and mutual influence. No psychological phenomenon can lay claim to any lawful determinate force and exhibit causal efficacy.

Can, however, objects of outer sense exhibit reciprocal causality as well as efficient causality? In the *Critique's* "Third Analogy of Experience", Kant maintains that the only way we can be aware of the objective coexistence of objects is if the objects all exhibit their determination by every other coexisting object. [27] Only then can consciousness be certain that all of these objects do exist together, rather than just being subjectively associated by consciousness ' faculty of imagination. The only way I can really know that these objects do objectively coexist is if their appearances reflect their mutual presence in a determinately necessary way. Since the necessity in question pertains to spatial objects with indifference to what they may be, the necessity is a material lawfulness. The mutual influence of coexisting objects must therefore be perceivably lawful in those terms that abstract from the qualitative nature of objects.

What physical relation involving motion can exhibit how each object is determined by every other object that simultaneously exists? What would provide the physical guarantor that the perceivable motions of objects can manifest their coexistence? The obvious candidate for this role is universal gravitation. Each object exerts gravitational force upon every other object and equally has gravitational force exerted upon it by all of them. If universal gravitation can be upheld, then it becomes intelligible how the principle of the reciprocal influence of all co-existing objects can hold sway over the physical nature we experience. Another candidate is Newton's Third Law of Motion: "To any action there is always an opposite and equal reaction, in other words, the actions of two bodies upon each other are always equal and always opposite in direction." [28] To the extent that this principle applies preeminently to impacts of bodies in motion relative to one another, it has a more limited application since it could only certify the coexistence of objects that are or have made contact.

Kant's Second Analogy maintains that all objective alterations we experience are necessitated in terms of efficient causality. This means that what objects are has no bearing upon

what changes they undergo. Instead, their alterations are due to factors independent of their nature . In other words, the alterations are material determinations. In light of the principles of causality and of reciprocal influence, these material determinations are somehow *both* diachronic and synchronic. That is, the material alterations of objects are necessitated by both antecedent and simultaneous conditions. Both necessitations must proceed at once, since otherwise, no objective events occur and no objects coexist. Is this possible? Can things be determined by what coexists with them at any moment and equally be determined by the antecedent state of affairs? How can both lines of determination operate without interfering with one another, canceling out their different vectors of efficacy?

The potential incompatibility of these two types of causality takes on a more concrete character insofar as each gets associated with a different type of motion. On the one hand, the diachronic causality in which antecedent conditions wield efficient causality, causing changes in motion, becomes associated with the externally determined inertial movements to which Kant restricts mechanics. These are exemplified by the communication of motion when one billiard ball impacts another. On the other hand, the synchronic causality of universal mutual influence is best associated with the motion determined by gravitational attraction. The latter involves the acceleration of falling bodies onto earth as well as the motion of orbiting planets in the solar system , of solar systems within a galaxy , and of galaxies within the universe. We need to consider whether these different types of motion can be coherently joined together or whether inertial motion is at odds with the whole system of gravitational attraction. In the former case, changes in motion occur that are external to each body , whereas in the latter case, bodies might be said to move themselves in virtue of the gravity they wield.

Mechanics in the ordinary sense considers matter as having inertia . This is equivalent to saying that changes of motion are external to matter. Matter does not move itself. If a body is at rest it stays at rest unless something else moves it. If a body is moving it maintains its velocity unless something moves it faster or slows it down. This property of inertia appears to conflict with universal gravitation because universal gravitation implies that matter moves itself, at least if bodies remain dispersed. Bodies then attract one another, moving themselves in virtue of that attraction. So as long as the universe contains a plurality of scattered bodies, they will seemingly never be able to exhibit inertia , since they will always exert force upon one another and draw themselves together.

These apparent discrepancies between inertial and gravitational motions bring a more concrete challenge to the problem of reconciling the two levels of causality to which objects of experience are subject in the *Critique of Pure Reason*. The reciprocal causality of coexisting objects operates synchronically in line with universal gravitation. The efficient causality of diachronic determination by antecedent conditions operates in line with the external imparting of motion in simple mechanics. We will have to see whether Kant's development of dynamics and mechanism can successfully integrate these distinct levels of causality and their respective motions.

Kant begins his dynamics by asserting in Explication 1 that "*Matter* is the *movable* insofar as it *fills* a *space*." [29] Earlier, in the Phoronomy, Kant also spoke of matter as moveable, but treated it merely as a point figuring in the "quantitative" formal relations of motion. Here we have matter being movable in respect to its occupancy of space. What supplies the authority of this initial specification of dynamics, that matter is moveable insofar as it fills space?

Can it just be an empirical fact, culled from experience? Kant has told us that we are here doing a metaphysics , providing the *metaphysical* foundations of natural science. This suggests

that we are developing something that has an a priori character, which will serve as the basis for a natural science that is ultimately going to be a science of matter in motion, that is, a science of mechanics. This science will provide necessary and universally valid laws of matter in motion. The natural science of mechanics will therefore not just be empirical, but provide, as Foster has pointed out, a physics that has a purely rational character. To achieve this, Kant cannot start from something that is merely empirical. An empirical starting point can never establish any principles that are strictly universal and necessary, for, as Kant never tires of pointing out, empirically grounded rules are always only provisional and corrigible, issuing as they do from particular observations. As Popper would say, further observations can always call them into question, but never establish their ultimate truth. [30]

It might seem that we can rely upon the principles of experience developed in the *Critique of Pure Reason*, which determine what holds true of objects of experience in general. Kant, however, insists from the outset of the *Metaphysical Foundations of Natural Science* that these synthetic a priori principles do not yet involve matter, and that matter is somehow something empirical in character. Matter does not derive its nature from the formal side of experience, but rather, Kant maintains, from the material aspect of experience involving sensation. In particular, Kant associates the experience of matter with one of its constitutive forces and the type of sensation that supposedly registers this force. The force by whose sensation we experience matter is repulsion. How do we experience matter thereby? We touch something and feel that it resists the impact of our body . Tactile sensation directly provides us with an experience of material bodies. [31]

By contrast, Kant maintains, matter cannot be directly perceived by means of the force of attraction . [32] Attraction does not give us any sense of the determinate size and shape of a body . It simply draws us towards its center, without providing contact with it.

In face of these claims, one is tempted to ask how directly one really experiences repulsion, and thereby, matter. Is repulsion, let alone matter, something one can simply feel? Or must one use judgment and thought to apprehend it? Is not matter something abstract, just like force itself?

We have been told that matter is moveable insofar as it fills space. What does it mean to fill space? To fill space, Kant asserts, is to resist everything that strives to move into a certain space. [33] A space that is not filled is an empty space. These claims suggest that filling space involves resistance and that resistance entails relation to some other entity that fills space and is moving into the former's place . After all, what fills space by resisting the entry of other things requires that there are other bodies similarly resisting the entry of other things into their place .

Kant's account thus seems to presuppose that there are already a plurality of bodies and that these are intruding upon one another and resisting each other's occupancy. Moreover, Kant seems to presume that there is empty space, for without it, bodies would not be in a position to have their space *entered*, repel one another, and break off the intruding contact.

Does the dynamic filling of space necessarily presuppose that there be empty space? Aristotle may identity place with the boundary of a physical substance, but he still suggests that places can be unoccupied. Descartes precludes any void by identifying material substance with extension. Space then is matter and matter is space. There is no empty space and all motion must take the form of vortexes where bodies slip by one another, always maintaining contact on all surfaces. Is Kant's mention of space that is not filled incidental, or must his dynamic account of matter require empty as well as occupied space?

Matter fills space through resistance insofar as some other moveable matter strives by its motion to press into the same place . That suggests that the intruding matter is changing its

location, which is to say that it was not in contact with the other matter filling space until it moved itself from some place into another. Repulsion appears to presuppose an antecedent separation. Resistance is directed at the incoming motion of another body , which apparently assumes some empty space to be traversed. Further, if repulsion resists the incoming motion of an intruding body , matter presupposes not only empty space, but a plurality of bodies. Matter will be in principle *a* determinate, particular matter, that is, a body resisting other bodies that equally resist it.

Something else crucially appears to be presupposed by this unfolding account. Namely, not only is matter determined to be moveable, but somehow bodies are in motion relative to one another. After all, there is no occasion for matter to resist anything, unless something is moving into its place . Motion is thus presupposed. This motion, however, is not supposed to be mechanical. As Kant indicates in his remark to Proposition 3, [34] the resistance here at play is not that which occurs when a body is moved from its place by another body . This is not a situation of the impact of one body upon another. Such mechanical interaction cannot occur unless each body already dynamically fills its own space. Only then can bodies offer the kind of elastic resistance accompanying the communication of motion, where, for example, one billiard ball careens of another. That communication of motion presupposes that bodies already occupy space with some degree of rigidity. Here, however, what lies at stake are the forces that enable matter to fill space in the first place , on the basis of which mechanical interaction can occur.

The repulsion ingredient in matter cannot be a force of resistance against some other moving body , for that takes for granted that each body dynamically fills its place , which is precisely what is in need of explanation. If matter were not already filling its space, there would be nothing for another body to invade. Kant has begun by presenting the dynamic account of matter in a quasi-mechanical way, which he himself recognizes is not appropriate because doing so presupposes the material filling of space that needs to be explained. Can Kant find a way of surmounting this dilemma?

In Proposition 1, which follows this initial explication, Kant asserts that matter fills a determinate space through a particular moving force, rather than by mere passive existence. [35] To overcome the Cartesian conflation of matter and extension, Kant invokes a principle he established in the “Phoronomy” section, that the only way a motion can be lessened or destroyed is by another motion in the opposite direction. This follows from the formal examination of how motions can be combined, where what appears to be a single motion can be analyzed into various combinations of two opposing motions. On these terms, the reduction of a motion can be resolved into the alteration of the relative velocity of two opposing motions, which combine into that single change. How does this principle give support to the claim that matter fills space with a particular moving force? To begin with, matter resists other objects moving into its space by lessening their motion. The only way that can be done is by offering an opposing motion that can be combined with their motions so as to diminish them. Matter must thus exert a moving force opposite to the incoming motions of other bodies. They are stopped from entering its space by an opposing moving force sufficient to counteract the intruding motion. That contrary motion is the only means by which matter can fill its space to the exclusion of anything else. Matter must exert a particular moving force, particular insofar as it should determine what specific boundary is occupied.

Kant’s discussion here is again parasitic upon the presence of another object that already fills a space of its own and that is coming into the space to be occupied by the matter in question. As Kant himself points out, this account of matter is not based upon the analytic principle that it is

impossible for two different bodies to occupy the same space at the same time . [36] Rather, the dynamic account of matter is what makes this principle possible. Logically speaking, bodies could be thought to occupy the same space simultaneously if they could coalesce and interpenetrate one another.

In thinking of this problem, one must keep in mind that matter as such cannot be coherently conceived to consist of material particles surrounded by empty space, which could allow porous bodies to merge. To avoid begging the question, matter must be accounted for with immaterial resources. One way of doing this is to think of matter as a type of force field, which, for the time being at least, might be conceived to consist simply in a force field constituting repulsion. Then, one can imagine a force field of repulsion approaching another and consider what might occur. Would the respective force fields mutually limit one another, so as to establish a determinate boundary at which they both begin and end? Or might they end up occupying the same space by combining their repulsive forces into a single body with correspondingly increased moving force?

Kant rejects the possibility of the latter coalescence. He maintains that if matter fills space with moving force, it is impossible for it ever to be penetrated by another body . [37] In Explication 2 of the *Metaphysical Foundations of Natural Science*, Kant complements repulsion with attraction, introducing them as together providing the two fundamental factors on which the dynamic account of matter depends. [38] Operating in conjunction, they will provide the resources for excluding any penetration of bodies by one another. Attraction and repulsion are both characterized as moving forces. Attractive force is described to be the moving force by which a body can cause other bodies to approach it and resist the movement of bodies away from it. Repulsion, conversely, is described as the moving force by which a body impedes the approach of other bodies towards it and pushes them away.

Kant invokes attraction and repulsion as the moving forces that are constitutive of matter, constitutive of the actual filling of space. He identifies them, however, in mechanical, rather than properly dynamical terms. Kant defines them in the mechanical framework of a relation between preexisting bodies that are in motion with respect to one another. Attraction and repulsion, as dynamic constituents of matter, should not be wielded by existing bodies upon one another, but instead make matter material in the first place , so that it can then enter into relations between particular bodies.

Kant's Proposition 2 might seem to avoid this mechanical account by proposing that "matter fills its space through the repulsive force of all of its parts" upon one another. [39] This repulsive force does not operate just on the surface of one body in opposition to other bodies that approach it. Instead, repulsion here operates internally throughout the space that matter fills. Thereby it is expansive force itself. Moreover, it can have a determinate degree, which can be smaller or greater with infinite gradations. [40] Since this intensive quantity may vary across equal volumes, it provides a possible basis for both differences in mass and differences in density .

Does this interpenetrating concept of repulsion, however, escape the pitfalls of Kant's mechanistic surface characterization? Kant describes repulsion as here being wielded by all the parts of matter, which repel one another throughout the space that matter fills. What, however, are these parts of matter that repel one another? They cannot be pieces of matter, for that presupposes material parts that already dynamically fill space. If such parts are in any way material, the whole account begs the question and simply goes round and round in circles. If parts must be invoked to make sense of repulsion, they must be immaterial. Matter should thus be composed of immaterial parts that exert repulsive force upon one another. To meet this

requirement, matter could be composed of “force fields” repelling one another and only thereby materially filling space. Matter would accordingly consist of immaterial parts each repelling one another. This notion present two aspects: matter as a whole and the repulsive forces comprising its immaterial parts. How are these parts to be distinguished and how do they belong to a whole, which thereby occupies a determinate space in a determinate manner?

The first dual challenge that needs to be addressed is determining how these parts are differentiated from one another and determining what keeps them together as parts of a whole. What makes these parts belong to one and the same specific matter as opposed to being particular bodies in themselves? Is there any difference? Leibniz conceived of matter in a dynamical way, but emphatically denied that matter ultimately had parts. The fundamental element of nature would be indivisible, a dynamic subject that keeps everything out of its space. Leibniz’s ultimate factor, the monad, after all, was to be determined in and through itself, independently of any relation to anything external. [41] Kant rejects that indivisibility and insists that space is filled by inherently divisible matter. [42] Of what, however, can these parts consist? They cannot themselves be material, although it may be granted that they have the potential to become incorporated in different smaller bodies when matter gets separated.

It is necessary to determine what the separation of matter into a plurality of bodies involves. If repulsion constitutes the continuous filling of space, can the separation of bodies be determined by that same repulsion? Can the mutual repulsion of the “parts” of matter provide for anything but an uninterrupted endless expanse of filled space? What can provide any boundary for the surface of particular bodies if only repulsive force can counter repulsive force and that mutual repulsion is itself the filling of space?

It might seem that the only way of distinguishing the parts of matter from one another is by their contiguity, by their contact with one another, which involves a spatial boundary at which each comes to an end where the other contiguous parts begin. This contiguity leaves no empty space between them. Under the framework of mutual repulsion, the only thing that can limit the extension of any part of matter or of a separate body would be the repulsion of some other part of matter or of another body . Otherwise, repulsion seems to dissipate to infinity. Hence, it would seem that mutually repelling force fields will not allow for any empty space. Insofar as repulsion can operate as a moving force only by countering the entrance of a moving force into its territory, that entrance will always involve contracting the expanse of one force field by another, rather than a traversal of empty space. If that is so, however, how can different bodies be distinguished from the extension of a single infinite material, whose parts mutually repel one another?

These difficulties all arise in respect to the attempt to fill space materially by repulsive forces alone. Can these problems be overcome when attraction is added? Attractive force is commonly conceived in mechanical terms, where the separation of bodies is presupposed and attraction operates between bodies that attract one another at a distance, being separated from one another by empty space. By contrast, repulsion is commonly conceived in similarly mechanical terms as a surface force, where one body repels another body from approaching its boundary.

In the dynamic account of matter, by contrast, both repulsion and attraction must operate within the entire volume of what fills space. Their interaction is what will provide for the determinate filling of space in the first place . Only on that basis, can mechanical repulsion and attraction occur, for without the dynamic constitution of matter , there are no bodies to interact.

Once bodies are constituted, then there may be both attractive and repulsive forces that operate at a distance across empty space. Gravity and attraction of opposite electro-magnetic

charges provide common examples of such attraction at a distance, whereas the repulsion of identical electro-magnetic charges provides a common example of repulsion at a distance. [43] Electromagnetic charges, of course, involve a polarity , where forms of matter are distinguished from one another as “positive” or “negative” in charge. This polarity is something very different from the complementarity of repulsion and attraction, since a body can just be “positive” *or* “negative”, whereas a body must involve *both* repulsion and attraction to be material.

One might ask whether the polarity of “positive” and “negative” charges is inherent in matter as such. If it were, of course, there could be no material factors that are merely “positive” *or* “negative”. One can grant separate “positive” and “negative” material factors, but if these are to be material and fill space, they will depend upon other, more primitive, moving forces for their dynamic constitution. Repulsion and attraction can thus be endemic to matter per se and make possible matter, which, in virtue of further natural determinations, has a particular electromagnetic charge that can attract matter of an opposite charge and repel matter of the same charge.

How then, can repulsion and attraction constitute matter in the first place , and set the stage for the operation of these different forms of repulsive and attractive force? By itself, repulsion might prevent the “parts” of matter from collapsing into a point. On the other hand, repulsion cannot hold matter together in any determinate way. The only way the mutual repulsion of the “parts” of matter can prevent their infinite expansion into dissipated nothingness is something else in matter countering that action. It makes no sense to appeal to the countering repulsion of other particular bodies. They themselves cannot have any separate centrality in distinction from the uninterrupted expansion of matter in general unless something more provides for their particular unity in opposition to other bodies.

As we have seen, Kant maintains that “matter fills its space through repulsive forces of all of its parts.” [44] This repulsion is not just on the surface, keeping out other intruding bodies, but also throughout the interior of the matter. Without that internal repulsion, the “surface” would be a periphery with nothing within to support it. The “surface” would implode and matter would occupy no volume. In order for any surface to have any material actuality, it must enclose a volume within which an expansive force exerts itself without any gaps.

Kant notes that this expansive force, by which matter internally fills space, has some specific degree. It must be determinate, and as such, it can be increased or diminished. To illustrate this, Kant describes what would happen if matter is compressed. In that case, forces are exerted against the internal expansive force with which matter fills its space. Here external forces act against the internal repulsive force. Kant points out that matter cannot avoid being compressible and thereby exhibiting a relative penetrability. [45] In other words, matter cannot escape being compressed if external forces are wielded against its surface, and this compression allows the space it occupied to be partially filled by the intruding body or bodies that wield the opposing moving force. Some compression is unavoidable since any countering moving force will diminish the moving force of the internal repulsion, just as opposing motions diminish one another. In order to prevent any compression, matter would have to have a repulsive force that cannot be diminished by any subtraction. That would require an infinite repulsive force, but an infinite repulsive force would render matter infinite in extension, precluding any other bodies as well as entailing the dissipation of matter into the equivalent of empty space. For just the same reasons, no matter can be absolutely compressed to a point and have its entire space taken over by intruding bodies. That would require an infinite intruding force wielded by some other body , which would also preclude the presence of any other bodies and expand the intruding entity to

limitless dimensions, leaving it indistinguishable from the void . [46]

One can see how complete penetration is precluded by examining how the geometry of the situation bears upon the magnitude of the contending forces. Grant that a repulsive force of some determinate magnitude be sufficient to allow matter to occupy a certain spherical domain. As the matter gets compressed, the same repulsive force is distributed throughout a diminishing volume as well as on a diminishing surface. The more the matter gets compressed, the more its expansive force gets concentrated. Indeed, this concentration will increase by a factor of the power of three because the volume of a sphere is $4/3\ \pi\ R^3$. By contrast, on Kant's account, the force of attraction is distributed on the surface of the sphere whose radius is the distance from the attracting body 's center. Since the area of the surface of a sphere is determined by $4\ \pi\ R^2$, the force of repulsion will increase at a significantly higher rate than would the force of attraction, as the repelled or attracted body nears the center of the repelling or attracting body . Accordingly, as the compression of matter increases, the force required becomes exponentially greater, making complete compression an impossibly infinite task.

Kant presents the expansive, repulsive force by which matter fills space as something wielded by every part of matter. These parts are in unbroken continuity with one another, like points in a line, lines in a plane, and planes filling a volume. The parts of matter repel one another such that there is no distance between them, yet still they are supposed to exert an expansive, moving force. Kant describes these parts as virtual points of infinitesimal breadth, leading one to presume that they are infinite in number. In effect, Kant maintains that matter is infinitely divisible, [47] even if the second antinomy presented in the *Critique of Pure Reason* suggests that reason can equally support the contrary view. [48]

Since Kant conceives the force of repulsion as being exerted by parts of matter, which fill space only by mutually repelling other parts, he must conceive these parts as occupying no determinate space of their own apart from the moving force they exert. That moving force, however, does not move parts away from where they stand, leaving unoccupied space. Rather, the parts are held in place by one another's repelling. This precludes not only any void in general, but any possibility that bodies could be separated by empty space. Indeed, since parts can be held in contiguity only by an expansive continuity of parts in all directions, matter seems to be inevitably a single infinite entity occupying all extension. Can matter then still be distinguished from empty space, let alone provide for the relations between bodies on which mechanics and all further determinations of nature depend?

Kant himself is aware to a significant degree of these looming problems. He acknowledges that repulsive forces cannot be relied upon to account all by themselves for how parts of matter stay in contact with each other. After all, if these parts are mutually repelling one another, what is to stop them from moving away in an ever expanding and ever more ethereal diffusion? [49] To avoid the Cartesian identification of matter and extension and the infinite dispersion of matter to emptiness, something else must keep matter contained.

Kant, of course, introduces a force of attraction to complement repulsion and give matter a determinate boundary. Before examining how this addition operates, it is important to note an assumption that has underlain Kant's preceding argument concerning the absolute impenetrability of matter. In establishing that matter is only relatively penetrable, Kant has presumed that whatever be the aggregate force of repulsion by which matter fills some space, it remains constant regardless of how the volume of that body alters. Kant is presupposing a conservation of energy , which entails that the compression of matter concentrates a constant force into an ever decreasing volume, whose surface will according exert an ever increasing

elastic repulsion. This alteration carries with it the idea that the same volumes of matter could contain very different amounts of repulsive force, depending upon how much that matter has been compressed. Matter can then fill space with very different degrees of force. This would appear to be equivalent to saying that equal volumes of filled space can contain different quantities of matter, that is, different amounts of mass . The basis for calibrating mass and the amount of mass per volume, or density , would seem to lie in nothing other than the amount of force a given volume of occupied space contains. We need to consider whether the force in question is just that of repulsion or also that of attraction. After all, Newtonian physics calibrates the mass of objects in terms of the force of gravitational attraction they exert. Is there any determinate connection between the force of gravity and the force of repulsion?

To address these issues, we must first consider the ramifications of Proposition Five, which asserts that "the possibility of matter requires *attractive force* as the second essential fundamental force of matter". [50] Kant offers a proof that attraction must supplement repulsion in order for space to be filled. His proof begins by claiming that the essential moving force that parts of matter receive from one another is the repulsive force being exerted throughout the matter. The parts of matter cannot be prevented from moving away from one another if only repulsion is in play. Not only will the parts separate, but they will have nothing to keep themselves together. Instead, matter will disperse to infinity, leaving neither any appreciable force nor any appreciable material at any places in the universe.

Kant points this out so as to show the necessity of attraction, but in doing so he presumes that repulsion can still be thought of by itself. Hegel will note that repulsion cannot even be conceived or be unless attraction is equally at hand providing for some coming together for repulsion to counteract, just as attraction cannot exert a force unless there is a repulsion keeping what is attracted apart. Repulsion without attraction instantaneously disperses into nothingness, just as attraction without repulsion instantaneously collapses into a point. In effect, there is no filling of space unless attraction and repulsion counter one another. [51]

Kant acknowledges this in Proposition 6, which maintains that "No matter is possible through mere attractive force without repulsion." [52] By itself, attraction would provide no occupation of space, since any would-be matter would disappear into a complete negation of volume, immediately becoming a mere point no different from the absence of material. This collapse would not be equivalent to a black hole containing a super dense conglomeration of matter, exerting so much gravitational force that light will somehow be unable to escape. Black holes require the presence of matter and the gravitational force exerted by mass . With only attractive force, there can be no matter to begin with, since matter must dynamically fill space, which requires repulsion as well.

Neither attraction nor repulsion can be without the other. In the absence of repulsion, attraction cannot engage in attracting, since attraction instantaneously disappears unless what is to be attracted is dispersed and resists collapsing into a point. Conversely, in the absence of attraction, repulsion has nothing to repel, but instantaneously disappears into the infinite dispersion of empty space. Nonetheless, Kant distinguishes attraction and repulsion and differentiates how they perceivably operate.

He claims that we immediately perceive repulsion in tactile sensations, whereas attraction cannot be immediately sensed. Instead, attractive force can only be inferred indirectly from perception. [53] Can this distinction hold up, given Kant's admission of how repulsion cannot operation without attraction? If one jumps up, does one not feel the attractive force of gravity immediately? In lifting one's foot or otherwise feeling the weight of one's body , does one not

feel attraction just as directly as one feels the repulsion of tactile pressure? Indeed, can one feel any tactile repulsion without feeling attractive pressure? After all, how can one feel oneself repelling an object that makes contact with one's body without equally sensing the attractive cohesion of one's body and that of the object?

If we immediately perceive repulsion, but only mediately infer attraction, it might seem that attraction derives from repulsion and is only an appearance reflecting the underlying reality of repelling force. On this view, what seems to be attractive force is actually the result of repelling forces contending with one another. In this way, a semblance of attraction really consists in a repelling force pushing something towards something else. Significantly, this "derivation" of attraction from repulsion employs mechanical terms, where different bodies exert force upon one another. It therefore cannot explain how these bodies fill space in the first place . As Kant has shown, a body cannot exert repulsive force upon another unless both dynamically occupy their respective spaces by combining both attraction and repulsion. Accordingly, attraction cannot be made derivative of repulsion, for both are coeval forces whose operation depends upon the counteraction of the other.

Nonetheless, Kant complements the alleged difference in perceivability of repulsion and attraction by alleging a corresponding difference in how repulsive and attractive forces operate. He characterizes repulsion as a surface force exerted by contact, when the boundaries of bodies impact upon another. By contrast, he characterizes attraction as a force that operates at a distance, without need of contact. [54] The force of attraction emanates from the center of a body and accordingly the magnitude of attraction in no way indicates the volume or shape of a body . Nor does the amount of attractive force determine the distance of the attracting object. The same attractive force could be wielded by something of smaller mass that is closer as by something farther away that has greater mass . These indeterminacies are absent in repulsion to the degree that repulsion is a surface force that operates in function of the shape and position of contacting material boundaries.

Can repulsion be just a surface force, operating by contact, if, as Kant himself has already argued, the surface of a body would implode if repulsive force did not penetrate every part within each body ? Does not the whole notion of surface forces involve a mechanical interaction of separate bodies, whose own filling of space must already be constituted by the dynamic interaction of repulsion and attraction? Does not the mechanical impact of bodies in contact involve contending surface forces that operate only on the basis of an internal penetrating repulsion that is counteracted by a pervading attraction?

Kant maintains that insofar as matter is dynamically constituted by both repulsion and attraction operating, we can understand the specific magnitude of a body being determined by the particular balance of these counteracting forces. Supposedly that particular balance will determine both the volume of the body and the amount of matter that it contains. [55] Does this make sense? Do repulsion and attraction provide sufficient resources for accounting for the determinate volume, mass , and density of a body ?

Kant is suggesting that repulsion and attraction arrive at a certain equilibrium determined by the magnitude of their respective expansive and compressive moving forces. The resulting equilibrium will supposedly determine the volume of the constituted matter. How is this to occur? The same volume of matter might seem to be producible by different balances of varying amounts of repulsive and attractive forces, which could be correlated with bodies of different densities occupying the same volume with varying amounts of matter. Besides the geometric determinations of volume, the only quantitative factors available are the magnitudes of attraction

and repulsion. The latter will have to balance one another out at a certain volume. Differences in mass and density would then depend upon varying quantities of these forces. Mass would be in proportion to the amount of these forces and density would be a function of that amount and the determinate volume at which their equilibrium is reached.

Kant provides us with a further account of how the particular balance will be achieved, based upon on the difference in how repulsion and attraction supposedly operate. Presuming the conservation of force in general, Kant maintains that repulsion distributes its particular force throughout the volume contained by the surface of matter. [56] Accordingly, the repulsive force will diminish with distance in function of the increase in the volume of the sphere that extends to that periphery. In other words, the repulsive force operating at the boundary of a body will be determined inversely to the volume of the entire body through which it will be evenly distributed. The volume of a sphere is determined in proportion to the cube of the radius (the volume of a sphere = $4/3\ \pi\ r^3$), whereas the area of the surface of a sphere is determined in proportion to the square of the radius (the surface of a sphere = $4\ \pi\ r^2$). If repulsion is a surface force and remains constant and is evenly spread throughout a spherical body , its magnitude will then vary in inverse relation to cube of the radius. Since, as Kant maintains, attractive force, distributes itself evenly on the surface of the sphere upon which it acts at a distance, attractive force will vary in inverse relation to the square of the radius of that distance. [57] Consequently, in order for attraction and repulsion to balance one another at a determinate boundary of material volume, the total attractive and repulsive forces must be of such a magnitude that at a determinate radius, the difference between them is sufficient to equalize the differences in the volume and surface area of the sphere that matter occupies. Since the volume of a sphere is determined in terms of the third power of the radius, whereas the surface is determined with respect to the square of the radius, whatever be the total force of repulsion and of attraction, they can maintain equilibrium only at a definite boundary, since any increase or decrease in volume will make them unbalanced. This is what allegedly allows the magnitudes of the two fundamental forces to determine the volume of matter, even if the same volume could be occupied by varying amounts of matter involving equilibriums of different magnitudes of attraction and repulsion.

This variability signifies that the volume of any matter and its respective density are contingent. Whatever these may be, attraction and repulsion will be at work, producing a specific balance in function of their different rates of increase and decrease as the volume of matter changes. Just how powerful these forces are cannot be determined by their concept. In other words, the geometrical formula applying to their operation must be supplemented by some constant, which cannot be derived from reason.

It should be noted that the dynamic constitution of matter through the equilibrium of repulsion and attraction pertains to matter per se. If it allows for considering materials with different densities, it does so without distinguishing bodies in terms of anything other than the geometry of space-time and the dynamic forces of matter in general. Although this dynamic account underlies further natural processes, it does not itself differentiate states of matter (such as gaseous, liquid , or solid states) nor particular elements nor electromagnetic phenomena nor chemicals.

In considering matters with different densities, Kant presumes that there can be different amounts of repulsive and attractive forces in a determinate filled space. Where would that variety come from, if these forces are generic to matter?

Further, Kant maintains that these forces are governed by law. Why should there be a law

pertaining to these forces? Admittedly, insofar as repulsion and attraction are constitutive of matter per se, their combination is universal to all material things. Moreover, since they constitute the filling of space in general, the manner in which they do so is invariable, even if the magnitudes of repulsion and attraction may vary in ways that are manifest in differences in volume and density . The same laws of repulsion and attraction will still be operative.

Kant's dynamic account may center upon repulsion and attraction, but there is another factor of central importance, whose independent status might be questioned. That factor is gravity and Kant associates it with the force of attraction in Proposition 7, which states that "the *attraction essential to all matter* is an immediate action of matter on other matter through empty space." [58] Here Kant seems to be suggesting that the attraction inherent in the dynamic constitution of matter is equally gravitational force, by which all bodies are attracted to one another. Although attraction is linked with gravity , there is still a distinction. Whereas attraction counteracts repulsion to enable space to be filled materially, gravity operates between constituted bodies. It does so based upon nothing more than the way attractive force operates in the dynamic constitution of matter. Since attraction does not depend on contact, but operates at a distance, its presence in matter per se entails that once attraction and repulsion together constitute bodies, the attractive force in matter will act as a universal gravitational attraction.

It may appear that gravity is a relation of mechanics, which revolves around how particular bodies interact on the basis of their dynamic constitution. Significantly, however, mechanics, as Kant chiefly develops it, involves inertial motion, where bodies communicate motion that is external to them. Gravity seems to be either ignored or irrelevant to the impacts and reactions under consideration. Nonetheless, attraction is gravitational by being wielded by a body with respect to others. Moreover, because attraction and repulsion are constitutive of matter as a particular body , matter, it seems, cannot fail to have both internal attractive force and external gravitational force.

Gravitational force presumably will be distributed evenly on the entire surface of the sphere extending from the center of a body to whatever object it gravitationally attracts. Accordingly, gravity will diminish in proportion to the square of the distance between the bodies in question. As Kant points out, the emanation of gravitational force should not be thought of in terms of rays of gravity , since that will leave gaps in space between the rays where gravity will not penetrate. [59] Gravity attracts universally throughout space, so its distribution must be thought of in terms of extending spherical surfaces on which it is homogenously distributed.

The dynamic account of matter thereby answers the question that Newton could not resolve: the question of why there is gravity . There cannot help but be gravity because the constitution of matter through attraction and repulsion creates particular bodies whose attractive force becomes wielded by each body as a force of attraction acting at a distance upon all other bodies. Since gravity depends upon the formation of bodies through the combination of attraction and repulsion, gravity is not just attraction, but an attraction mediated by the unity of attraction and repulsion.

Notes

1. Kant, *Metaphysical Foundations of Natural Science,* Proposition 2, Proof, 499, p. 36; Proposition 5, Proof, 509, p. 46.

2. Kant, *Metaphysical Foundations of Natural Science*, Propositions 8, Note 2, 518, p. 56.

3. Kant offers the latter, question-begging mechanical account, writing, "*Attractive force* is that moving force by which a matter can be the cause of the approach of others to it (or what is the same, by which it resists the removal of others from it). *Repulsive force* is that by which a matter can be the cause of others removing themselves from it (or what is the same, by which it resists the approach of others to it)." See Kant, *Metaphysical Foundations of Natural Science*, Explication 2, 498, p. 35.

4. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), Remark to §262, p. 45.

5. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §254, p. 28.

6. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), *Zusatz* to §254, p. 30.

7. Kant, *Critique of Pure Reason*, A25, B39, p. 158; A32, B47–48, pp. 162–163.

8. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §254, p. 28.

9. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §256, p. 31.

10. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §256 and Remark to §256, pp. 31–32.

11. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), *Zusatz* to §254, p. 30.

12. Einstein will invoke "Gaussian co-ordinate systems" as the fundamental contexts of his General Theory of Relativity. See Albert Einstein , *Relativity: The Special and the General Theory*, trans. Robert W. Lawson (New York: Three Rivers Press, 1961), p. 108.

13. Aristotle , *Physics*, Book IV, Chap. 1, 208b12–22, in *The Complete Works of Aristotle* , I, p. 355.

14. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), *Zusatz* to §257, p. 34.

15. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), *Zusatz* to §259, p. 37.

16. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §259, p. 37.

17. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §261, p. 41.

18. Hegel, G. W. F., *Philosophy of Nature* , trans. A. V. Miller (Oxford: Oxford University Press, 2004), §261, p. 41.

19. Consequently, Aristotle is left to remark in the Metaphysics , "matter is unknowable in itself." See Aristotle , *Metaphysics* , Book VII, Chap. 10, 1036a8, in *The Complete Works of Aristotle* , II, p. 1635.

20. Aristotle , *Physics*, Book I, Chap. 9, 192a25–34, in *The Complete Works of Aristotle* , I, p. 328.

21. Admittedly, Aristotle at times suggests that artifacts are not genuine substances since the "form" embodied in products of craft is not an active form, like that which "ensouls" natural substances. Whereas substances have an independent being, artifacts must incorporate substance, giving some natural material, which is already ensouled as "wood", "stone", etc., a further externally imposed design.

22. See, for example, Aristotle , *Metaphysics* , Book VII, Chap. 5, 1030b28–1031a2, in *The Complete Works of Aristotle* , II, pp. 1627–1628.

23. Kant, *Metaphysical Foundations of Natural Science*, 477, p. 12.

24. Kant, *Metaphysical Foundations of Natural Science*, 477, p. 12.

25. Kant, *Critique of Pure Reason*, B291–293, pp. 335–336.

26. Kant, *Metaphysical Foundations of Natural Science*, 470, p. 5; 478, p. 13.

27. Kant, *Critique of Pure Reason*, A211–215, B256–262, pp. 316–319.

28. Newton, Isaac , *The Principia: Mathematical Principles of Natural Philosophy*, trans. I. Bernard Cohen and Anne Whitman (Berkeley & Los Angeles, University of California Press, 1999), p. 417.

29. Kant, *Metaphysical Foundations of Natural Science*, 496, p. 33.

30. Since empirical theories may be falsified by observations, but never strictly confirmed, we

must admit, Popper notes, “that scientific theories are never fully justifiable or verifiable, but that they are nevertheless testable.” See Popper, Karl , *The Logic of Scientific Discovery* (London: Routledge, 2002), p. 22.

31. Kant, *Metaphysical Foundations of Natural Science*, Proposition 5, Remark, 510, p. 48.

32. Kant, *Metaphysical Foundations of Natural Science*, Proposition 5, Remark, 510, p. 48, Proposition 7, Remark 1, 513, pp. 50–51.

33. Kant, *Metaphysical Foundations of Natural Science*, Explication 1, 496, p. 33.

34. Kant, *Metaphysical Foundations of Natural Science*, p. 38.

35. Kant, *Metaphysical Foundations of Natural Science*, p. 34.

36. Kant, *Metaphysical Foundations of Natural Science*, Proposition 1, Remark, 498, p. 35.

37. So Proposition 3 states, “Matter can be *compressed* to infinity, but can *never* be *penetrated* by a matter, no matter how great the compressing force of the latter may be.” See Kant, *Metaphysical Foundations of Natural Science*, 501, p. 37.

38. Kant, *Metaphysical Foundations of Natural Science*, 498, p. 35.

39. Kant, *Metaphysical Foundations of Natural Science*, 499, p. 36.

40. Proposition 2 reads in its entirety: “Matter fills its space through the repulsive forces of all of its parts, that is, through an expansive force of its own, having a determinate degree, such that smaller or larger degrees can be thought to infinity.” See Kant, *Metaphysical Foundations of Natural Science*, 499, p. 36.

41. See Leibniz, Gottfried , *Monadology*, sections 1–11, in *Classics of Western Philosophy*,7th Edition, ed. Steven M. Cahn (Indianapolis: Hackett, 2006), p. 619.

42. Proposition 4 states, “Matter is *divisible* to *infinity*, and, in fact, into parts such that each is matter in turn” (Kant, *Metaphysical Foundations of Natural Science*, 503, p. 40).

43. Important questions will need to be answered with respect to forces, such as gravity and electromagnetic forces, which seemingly operate at a distance. How can it be that the gravitational force exerted by one body upon another is not diminished by any other object coming in between? Will this be true of electromagnetic charges? Can anything intermediary interrupt an electromagnetic field and alter how the repulsion and attraction of electromagnetic forces operate across empty space?

44. Kant, *Metaphysical Foundations of Natural Science*, Proposition 2, 499, p. 36.

45. Kant, *Metaphysical Foundations of Natural Science*, Explication 4, 501–502, p. 38.

46. Kant, *Metaphysical Foundations of Natural Science*, Proposition 3, Proof, 501, p. 38.

47. So Proposition 4 affirms, "Matter is *divisible* to *infinity*, and, in fact, into parts such that each is matter in turn" (Kant, *Metaphysical Foundations of Natural Science*, 503, p. 40).

48. Kant, *Critique of Pure Reason*, A435–443/B463–471, pp. 476–483.

49. Kant, *Metaphysical Foundations of Natural Science*, 508, p. 46.

50. Kant, *Metaphysical Foundations of Natural Science*, 508, p. 46.

51. Hegel, G. W. F., *Science of Logic*, trans. A. V. Miller (New York: Humanities Press, 1969), pp. 174–177, 182–183.

52. Kant, *Metaphysical Foundations of Natural Science*, 510, p. 48.

53. Kant, *Metaphysical Foundations of Natural Science*, 509–510, 513, pp. 47–48, 50–51.

54. Kant, *Metaphysical Foundations of Natural Science*, 516, pp. 54–55.

55. Kant, *Metaphysical Foundations of Natural Science*, 517–518, 524, pp. 56, 62.

56. Kant, *Metaphysical Foundations of Natural Science*, 501, p. 38.

57. Kant, *Metaphysical Foundations of Natural Science*, 517, p. 55.

58. Kant, *Metaphysical Foundations of Natural Science*, 512, p. 50.

59. Kant, *Metaphysical Foundations of Natural Science*, 519, p. 57.

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5. Matter and Motion

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Why is space filled with matter, rather than wholly empty? The answer lies in how space entails time , how time and space together involve place , how the difference and identity of place entails motion, and how motion entails that place remains self-identical while being indifferent to its spatio-temporal alterations, which requires the exclusivity that repulsive and attractive moving forces constitute.

It makes no sense to ask why in general there is something rather than nothing, for the question asks for some ground to generate something. That means that the question begs itself, for it invokes something to account for why there is something rather than nothing. There can be no ground or reason for determinacy in general. Determinacy just results from indeterminacy insofar as being is nothing and nothing is being and the becoming that is comprised by both ceasing to be and coming to be cancels its own ceasing to be and becomes a unity of being and nothing. Being, unlike determinate being, has no specific character, nor any determinate relation to something else. All attempts to characterize being end up conflating being with something determinate. Hence, being is indistinguishable from nothing and is immediately nothing, without having to undergo any process or transition. Similarly, because nothing is completely devoid of any specificity, it is equally being. Being that is nothing and nothing that is being together constitute becoming, which combines ceasing to be (being that is nothing) and coming to be (nothing that is being). Since, however, the nothing that being is just as much immediately reverts to being, ceasing to be ceases. Conversely, since the being to which nothing immediately reverts is itself immediately nothing, coming to be immediately cancels itself. Together, this renders the two sided process of becoming an immediate unity of being and nothing, immediate insofar as it rests upon nothing else but the dual indeterminacies of its components. The unity of being and nothing in the form of being, however, is neither being nor nothing nor becoming but the minimal specification of determinacy, which cannot be constituted out of anything determinate, but can only arise from what is indeterminate. [1]

Similarly, matter cannot be generated by anything material. It must be the result of the immaterial natural factors of space and time , whose constitution of place and motion provides that which is necessary to account for matter in terms of “moving forces” of attraction and repulsion. This development obviously has theological implications, since it means that we need not appeal to something outside of nature to account for matter.

To clarify how matter and its fundamental forces are determined, let us continue our three ring circus and revisit each of the great pioneers of the philosophy of nature in their efforts to

deal with the most elementary aspects of nature . It makes sense to look first at Aristotle , then at Kant, and finally at Hegel, keeping in mind that Kant will soon bid farewell to our explorations of nature . This is because Kant, unlike Aristotle and Hegel, will regard the mechanics of bodies in motion to be the only domain of nature about which anything truly a priori can be determined. Indeed, Kant will restrict his pure mechanics to inertial motion and leave out of account the different aspects of gravitational motion that Hegel will analyze under the headings of “fall ” and the “absolute mechanics” of planetary motion. We will have to consider whether Kant’s failure to address these further aspects of mechanics reflects how Newton attempts to derive the theories of Galileo and Kepler from more elementary principles of motion.

5.1 Aristotle's Account of Locomotion and Its Relation to the Other Changes of Nature

Before considering the limits of Kant's pure mechanics , it is worth examining how locomotion figures in Aristotle 's *Physics*. Aristotle , as we have seen, does not conceive nature as an objectivity governed solely by laws of matter, as early modern philosophers up through Kant will do. Whereas such mechanistic laws of matter are indifferent to the form and import of the things they govern, Aristotle insists that locomotion is determined not just by efficient causality, but by formal and final causality as well. Although locomotion consists in changes of spatial-temporal position that can apply to bodies in general, no matter what they are, the fundamental character Aristotle ascribes to natural entities connects locomotion to the specific nature of the moving object. What distinguishes nature from other types of being, for Aristotle , is that natural substances have a principle of motion lying within them, a principle that is further linked to the particular kind of thing that they are. The form of natural entities is active and this self-active character entails self-motion in the general sense of undergoing change of some sort in virtue of itself. Movement, understood as locomotion , is not the same thing as change, for locomotion is a particular type of change.

On Aristotle 's account, there are three types of change that apply to natural substances. None should be confused with coming to be or perishing, for change pertains to the alteration of a persisting substance. In each case of change, contraries are involved which apply to some substance. The three types of change are qualitative change, quantitative change, and movement. These respectively involve change of quality, of magnitude, and of place over time . Change of quality is termed alteration, change of magnitude is termed increase or decrease, and change of place over time is termed locomotion . [2]

When Aristotle characterizes what is natural as having a principle of motion internal to it, he leaves unspecified which of the three kinds of motion is involved. As we have noted, Aristotle maintains that locomotion is the primary form of change (*kinesis*). Locomotion has primacy because the other kinds of change depend upon it, whereas locomotion does not itself depend upon them. In other words, locomotion does not automatically carry with it alteration or change in magnitude, but alteration and increase and decrease cannot occur without locomotion . Aristotle gives a series of different arguments supporting the primacy of locomotion in respect to the two sides of that primacy. Namely, locomotion can occur without alteration and locomotion can occur without change in magnitude, whereas locomotion will underlie alteration on the one hand and increase and decrease on the other. [3]

Locomotion might be understood to be primary with regard to time , yet such temporal primacy seems contradicted by some remarks Aristotle makes concerning how locomotion comes last when we consider all the changes a substance undergoes. A change in magnitude, for example, will alter the place occupied by a natural substance and involve locomotion at least with regard to its boundary, which will move with every increase or decrease of its volume. Similarly, an alteration of quality that affects magnitude will entail movement of the same sort. [4]

Nonetheless, even in such cases, Aristotle suggests in Chap. 7 of Book 8 of the *Physics*, the change that entails movement of boundaries will be precipitated by an underlying locomotion . [5] In order for an individual natural substance, such as a living thing, to come to be, locomotion is necessary. The "becoming" of a natural thing, of course, is not equivalent to creation ex-nihilo. It

will involve some preexisting formed (and therefore actual) matter taking on a new form which will then give the emergent entity its own tendencies towards motion. This change in form is based upon some locomotion on the part of what instigates this form alteration. Something must act upon the given formed material to transform it and this depends upon entering into some new relation to that material, requiring a change in proximity.

For example, for something to undergo a change from one quality to another, some contrariety must enter in, whereby what alters no longer has its initial quality but acquires something else. This involves minimally a privation and then some further quality, both of which may entail change in magnitude. Qualitative change is, of course, different from that of locomotion . Locomotive change has a seamless continuity, due to the continuity of its constitutive factors, space and time . [6] Further, circular movement, which Aristotle understands to underlie all further locomotion , has a fundamental unchanging regularity. Namely, circular motion begins and ends at the same point and thereby has the potential of being eternal. Although not all circular motion need be eternal, the fact that circular motion has no built in endpoint makes it a proper candidate for unceasing motion that could generate motions that begin and end in a distinguishable way. In any event, no matter what kind of locomotion we consider, we are dealing with the traversing of space and time . Both of these factors are continuous, infinitely divisible into moments that are homogenous and therefore exhibit continuity. By contrast, alteration, namely, qualitative change, is essentially not homogeneous and therefore not continuous.

Oddly enough, Aristotle maintains that change of magnitude is not continuous, like the change of place comprising locomotion . He claims that change of magnitude involves contraries that are qualitatively distinct, such that even though quantitative change appears to increase or decrease what is homogenous, there is a qualitative discontinuity. With purely continuous change, there cannot be any boundary to the changes, since each quantum is in continuity with others both smaller and larger than it. Natural things, however, cannot infinitely increase or diminish in any quantitative respect. They have a quantitative limit, to which qualitative change is associated. In other words, natural things have a measure, that is, a determinate range of magnitude that is bound up with what they are. A quantitative limit that is tied to quality is precisely what comprises measure. To the extent that natural things have a measure, there is a certain range of magnitude within which they remain what they are, but if their magnitude increases or decreases beyond a certain point, they lose their defining character. [7]

Why this is so requires some kind of argument and that argument is to be found in how what is natural has a form that entails a boundary or limitation that sets each kind of natural object qualitatively apart from other kinds of natural things. Parts of space and moments of time may be bounded by one another, but they cannot be qualitatively distinguished unless something qualitatively distinguishable occupies some place in space-time . As Aristotle maintains, one can distinguish up and down qualitatively in virtue of kinds of natural substances that gravitate to certain places owing to their distinguishing active form. Consequently, although locomotion may be continuous, such that natural entities may move without altering in form or changing their magnitude, change in magnitude can involve nodal points where measure asserts itself, introducing non-continuous changes that alter the form of things.

How then does alteration, that is qualitative change, depend upon locomotion ? Aristotle presumes that to produce qualitative change there must be a mover and something else that is moved by it. Here mover and moved refers to all three kinds of change, such that locomotion requires a mover to move what changes its place , alteration requires a mover to alter the form of

a natural substance, and change in magnitude requires a mover to increase or decrease something else. Despite the fact that nature is distinguished by an active form that supposedly precipitates changes in accord with the specific nature of the natural substance, Aristotle still assumes that there cannot be any truly independent self-motion, but that motion depends upon the moved to be set in motion by a separate mover. [8] In the case of qualitative change, the alteration of form depends upon a mover coming into contact with what it causes to alter. This requires the mover and the moved to change their relative positions so that a contact that was not at hand comes into play. Accordingly, the contact on which alteration depends requires locomotion . Aristotle seems to be ruling out any action at a distance by which a mover can cause something else to change without making contact. Even if he were to accept action at a distance, the change such action precipitates would still require some change in that action at a distance, since otherwise the mover would be acting in a changeless manner, such as might support the eternal orbits of celestial motion. Hence, once more any alteration would presume locomotion if that action is relative to the distance at which it is wielded.

Since the Aristotelian account of change operates in terms of the relation of mover and moved, the three types of motion (change) will involve three types of movers, each of whose action depends on some sort of locomotion . Alteration (change of form) is not continuous, but occurs at some point and moment, preceded by a period in which there is no such alteration. If alteration arises through contact, the factors involved are first not in contact and then are brought into contact. To bring the factors into contact, a mover is required to move at least one of them. Hence, the requirement of a change in proximity entails that qualitative alteration depends upon locomotion .

Nonetheless, the dependency of alteration upon locomotion does not mean that change in form can be reducible to locomotion . Not only does locomotion involve continuous change in place , but locomotion can occur without any substance undergoing alteration or change in magnitude. Although locomotion may be an enabling condition for alteration, something more must be invoked to determine whatever change in form occurs.

The same is true for the increase or decrease of natural substances. Locomotion may be the basic facilitator of all natural processes, but changes in quantity, like those of quality, remain determined by further natural principles and cannot be equated with movement. Take the case of a natural substance that grows. The boundary it occupies alters spatially over time . In other words, the surface undergoes locomotion even if the center of the substance does not change. Further, growth depends upon obtaining nutrients and expelling wastes, both of which involve locomotion . Conversely, when a natural substance diminishes in size, its parts become separated, be it by evaporation or other forms of decomposition. Whether something splits apart or combines with other material, locomotion is at hand. Thus, even though locomotion need not be associated with quantitative change, quantitative change cannot occur without locomotion .

Given the primacy of locomotion , how can Aristotle ’s invoking of the relation of mover and moved be reconciled with his fundamental claim in Chap. 1 of Book II of the *Physics* that nature has a principle of motion residing within it? [9] Although this motion can be a change in form, a change in magnitude, or a change in place over time , it rests upon locomotion . Do natural things then move themselves from place to place on their own or are they set in motion by something else? One might think that nature must be self-moving, yet Aristotle rejects the very possibility of self-motion and instead invokes the relation of mover and moved, where what undergoes movement is set in motion by something else, and what moves something else does not move itself. On this basis, motion must ultimately rest upon an unmoved mover. Otherwise

everything is moved by something that is moved by something else ad infinitum, with no locatable source of motion. Can nature contain an unmoved mover and how can such a source of motion be conceived?

These questions would not arise if there can be at least one natural substance that is self-moving. Why does Aristotle rule out self-motion, and in particular, self-locomotion ? The question of continuity comes into play here. Imagine the case where motion is not continuous. Let us think of motion in terms of alteration, for alteration happens in a discontinuous fashion, where first there is some quality in a substance and then it is no longer there and some other quality may have supplanted it. If natural things are not self-moving there has to be a mover for something else will have to set what alters in motion. What, however, will cause that mover to set the moved in motion and what will determine when this occurs? If something sets something else in motion it should immediately go about doing what it does. In the case of alteration, a qualitative change should follow at once without any interval or gradual emergence. For such change to occur, rather than be immediately at hand, there will need to be a kind of continuous motion in the background, which at some point when sufficient contact is obtained, precipitates discontinuous alteration. This applies equally to change in magnitude, which, as Aristotle has maintained, has its limits where measure enters in. Locomotion must make its continuous traversal in order for the increase or decrease of a natural substance to make its bounded appearance.

Accordingly, if there is no self-motion and nature is to be true to its defining character and be in process, an unmoved mover must engender an ongoing ceaseless locomotion which can occasion the discontinuous motions of alteration and changing magnitude. In Chap. 1 of Book VII of the *Physics* Aristotle presents his argument for how motion follows from an unmoved mover. [10] He begins by noting that everything that is in motion must be moved by something else. Since, as we have seen, all types of motion depend upon or are locomotion , motion is produced ultimately by producing locomotion . Locomotion involves the change of place over time of a natural substance that occupies space. As such, that substance is not just a point, but an extended entity. Thus it is divisible into parts. Consider a natural factor that is divided merely into two adjacent parts, AB and BC. As Aristotle observes, AB cannot move unless BC moves as well. If BC is at rest, then AB cannot be moving. Therefore, Aristotle concludes, no natural substance can be self-moving, for the motion of each of its parts depends upon the motion of other parts. Accordingly, each natural thing that is in motion consists of a moving part that is a mover and a part that is moved by that moving part. [11]

This argument exhibits a recurring predilection permeating the ancient philosophy classically developed by Plato and Aristotle . The unwillingness, indeed, inability to conceive self-motion has its parallel in the unwillingness and inability to conceive self-control or self-determination. In Book IV of the *Republic*, Socrates takes up the issue of self-control and points out how it is inconceivable. [12] For there to be self-control, and more generally, self-determination, agent and patient would have to be the same, but it would be contradictory for something to act upon itself and be both agent and patient at the same time . Hence, in both the polis and the soul, there must be a division between one part that rules and another part that is ruled over. The ruling part of the polis does not act upon itself but acts upon subject classes, just as in the soul there is a ruling part that rules over the subordinate parts of the soul. Self-determination is thus unthinkable. Aristotle similarly maintains in his *Politics* that although political association is properly an association of equals, they cannot exercise self-rule, but rather rule in turn, so that at every time , only some occupy the position of ruler, acting upon other subjects who later will have a chance to do the

same. [13] This division into ruling and ruled parts carries over into Aristotle ’s account of the soul as well. He divides the intellect into active and passive parts, such that the active intellect acts not upon itself but upon its passive counterpart. [14] Once more there is an unwillingness or inability to allow for any kind of self-determination.

This leaves us in perplexity, for self-motion cannot be at the root of all motion when what leads to an infinite regress of mover and moved is the denial that there can be self-motion. All locomotion is caused by something other than what changes place because moveable substance is thought of as being material and therefore divisible into parts, where the motion of one part depends upon that of the part adjacent to it. What is immaterial, by contrast, does not have parts, lacks potentiality, and does not change in any respect. It can only engage in thinking itself. [15] How then is immaterial substance going to impart any motion upon material substances? Self-thinking thought cannot provide any formal causality because the only form it has is its own form, which is not a form that any material substance can share. Further, immaterial substance cannot wield efficient causality, which requires being able to move itself. Aristotle is left appealing to final causality. Somehow material substances are to be moved by immaterial substance in the way in which a lover is moved by the beloved—by a kind of teleology. [16] One must ask, however, how teleology can possibly operate here. In what way could something material do anything that can be said to realize self-thinking thought? Immaterial substance has no potentiality and its self-thinking thought does not depend upon anything else for its own realization. It just does its own thing ceaselessly in a completely placeless and timeless manner.

Aristotle contends with this unchanging efficacy of immaterial substance by alleging that its final causality can impart a locomotion that somehow fits the ceaseless unchanging character of self-thinking thought. That eternal invariable locomotion is uniform circular movement, which is then somehow going to produce other kinds of locomotion , [17] which will then facilitate alterations and changes in magnitude. [18] This possibility depends upon natural things having different forms in virtue of which they are subject to different types of processes. Even if locomotion might be said to be indifferent to the qualitative and quantitative changes it facilitates, the specific natures of natural substances permits change of place to produce the other types of change. Thus there is a type of locomotion , eternal uniform circular movement, which is inherently external to terrestrial things, but not external to nature itself. There can be no locomotion outside of nature , since the change of place of material substance is a natural occurrence within the universe. The unmoved mover is not in locomotion or in motion of any other sort. Accordingly, all motions, that is, all changes take place in nature . Nevertheless, although there are no motions outside of nature , the changes in nature are somehow produced ultimately by a mover distinct from everything that moves.

How then can nature retain the defining character that Aristotle gives it, namely, that it has the principle of motion within itself? Admittedly, all change occurs within nature . If, however, mover and moved are always distinct, how can natural substance contain the principle of its motion? Does not the unmoved mover put that principle beyond everything material?

A partial redemption of Aristotle ’s concept of nature might be provided by recognition that how things in nature alter is determined by what they are. In that respect, the way they move is determined by a principle residing in them, even if their motion has an enabling condition that comes from without. This gives us a way to think also about how locomotion could be basic and yet generate alterations that involve more than simply movements of bodies in space and time . In doing so, of course, we must presume that those bodies are not just material entities with mass , but substances with active form, as Aristotle claims.

On this account, locomotion obtains a character that stands in important contrast to how motion gets thought of in Kantian mechanics. Whereas Hegel expands mechanics to involve motions of fall and celestial gravitational systems, Kant's mechanics is focused upon inertial movement, even if gravity is acknowledged. Motion is regarded as fundamentally external to bodies in that the movability of bodies does not entail that any particular body is in motion or rest. Rather, a body can be in motion or not in motion, and which of these states it is in is subject to change only due to the external action of some other body . Bodies, in other words, have inertia and remain in uniform motion or rest until some moving force is exerted upon them. Aristotle rejects any principle of inertia , even though he denies all self-motion. If a material substance is moving it will not continue moving unless some force is applied to it. Conversely, a material substance at rest will not continue at rest unless something prevents it from moving to the place at which its nature directs it.

Aristotle argues against something staying in motion unless something else is moving it by pointing to the allegedly absurd consequences of inertia . Since whatever moves must be material and be divisible, no part of it can continue in motion without moving and being moved by its contiguous sections. [19] This would contradict inertia , as would the natural tendency of material things to arrive at their proper place . Aristotle 's argument thus reflects two basic strictures of his *Physics*: the affirmation that nature has a principle of motion within it and the denial of self-motion. He correlatively maintains that it makes no sense to speak about motion being in motion. [20] This might appear to be a blanket denial of acceleration , but Aristotle is not blind to changes in rates of change, so long as that acceleration is not a result of an application of external force to inertial motion.

Significantly, when Aristotle speaks about locomotion , he ultimately divides it into pushing, pulling, carrying, and twirling, all of which exhibit a mover moving something else. [21] He further maintains that carrying and twirling can be reduced to pushing and pulling. [22] The reduction of locomotion to pushing and pulling bears some resemblance to the two dynamic forces on which Kant bases matter: repulsion and attraction. Insofar as locomotion is primary for all types of change, pushing and pulling has a comparable fundamental role in the processes of nature . Since, however, natural substances undergo change, including locomotion , in function of their specific nature , there can be no continuous pushing and pulling that is generic to material substances. Gravity , as an attractive force rooted in matter, cannot be present, any more than inertia .

What ramifications does Aristotle 's exclusion of gravity have?

Whether a particular substance would be at rest or in motion would depend upon its specific nature , its location, and the contingent location of other substances. A body of earth might be at rest, for example, because some other rigid body is preventing it from falling further to its natural resting place , just as fire might not be able to rise because of some barrier. In such situations, the state of rest or motion of a natural substance would be in some degree external to its specific nature , owing to its chance relations to other substances.

Nevertheless there remains some respect in which the principle of motion lies within the natural entity, not in function of its mere mass , as with gravity , but in function of its specific nature as a type of natural entity. Inertia is thereby precluded, since it renders the motion of bodies something external and indifferent to what they are.

Although Aristotelian nature allows for neither inertia nor gravity , one might wonder whether inertia and gravity fundamentally conflict with one another. Inertia entails relations between bodies where objects are placed into motion or rest by something external, namely some

other body that exerts moving force upon something else, having been set into motion or rest in the same external manner. Gravity is an efficient cause of motion that acts at a distance on other bodies irrespective of the nature of the bodies being affected. All that counts is the mass and relative distance of the objects in question.

Through gravity , objects not only act upon other bodies but seem to move themselves, accelerating towards their most powerful center of gravity in function of both the force wielded by that center and the gravitational attraction wielded by the mass of the falling object. This produces systems of moving bodies whose locomotion operates through nothing other than the gravitational forces they exert upon one another. No unmoved mover is needed as an ultimate source of motion. Rather, matter has a principle of motion internal to itself—namely, gravity , grounded on the attraction and repulsion together constituting bodies of matter. Gravity thus seems to overcome the externality of motion emblematic of inertia . Bodies will not remain at rest or in uniform motion so long as matter exerts gravity , unless gravitational forces neutralize themselves or are so small that their effects are virtually unnoticeable. [23]

Can there then have been a time in which there was matter, but in which there was no locomotion ? Aristotle must answer no, for he has argued that what guarantees the continuity of the time is the eternal motion of those entities moved by the unmoved mover. Time always requires locomotion , so there cannot be any moment in which no matter moves. Conversely, there cannot be any motion without matter, for change of place over time cannot occur without eternal celestial locomotion and the further changes it occasions. Accordingly, natural matter must itself be eternal, for otherwise there could not be the eternal celestial motion on which time itself depends.

Eternal matter cannot be created. It is simply at hand and it does not come into being or perish. What becomes or perishes is not matter but particular substances that combine matter with some form.

There is little to be said about the relationship of the unmoved mover, which consists of self-thinking thought, and the heavenly bodies. They owe their motion to the unmoved mover, which never begins or ends its production of locomotion . Somehow the purely intellectual unmoved mover eternally moves celestial bodies and through their locomotion engenders all other change. The heavenly bodies are physical entities with matter, whereas the unmoved mover, the highest being, can have no matter, since it must be fully actual and devoid of any potential. Otherwise, the unmoved mover would be susceptible of change. The unmoved mover would then forfeit its unmoved primacy as the source of all change, given the denial of self-motion. The unmoved mover cannot depend upon anything else and cannot be susceptible to any alteration. It can only be directed at itself and yet somehow its self-directed, self-thinking pure actuality must serve as an unmoved mover. It is needed due to the presumption that there cannot be self-motion and that thereby nature itself cannot provide for the change it undergoes. We must look outside nature for something that would be a source of motion, which as a source cannot itself be in motion. The daunting problem of the unmoved mover is no longer an issue for the pure mechanics of Kant or the more comprehensive pure mechanics of Hegel. For neither Kant nor Hegel need we look outside of nature for any source of motion.

For Aristotle , however, the eternal celestial locomotion at the root of all other change in nature cannot be self-engendered. Although the continuity of time may depend upon the eternality of celestial locomotion , this does not mean that all matter has to be moving continuously. How, then, can the continuous motion of heavenly bodies produce change that is not continuous, be it transient locomotion or discontinuous alteration or discontinuous change in

magnitude? Can the eternal celestial motion in nature account for all other natural change?

Although all change may be precipitated by continuous, circular celestial motion, Aristotle can hardly ignore that nature contains discontinuous locomotion , where natural substances come to rest and then are set in motion anew. In *On Generation and Corruption*, Aristotle ties the production of discontinuous locomotion to the inclination of the heavenly spheres with respect to the earth, which causes the eternally moving celestial body to be “alternately remote and near”, rendering its “movement irregular” with respect to terrestrial substances. [24]

The need to provide such an account is specific to Aristotelian *Physics* and no more haunts the more modern approaches to nature than does the problem of the unmoved mover.

5.2 The Abiding Problem of Self-motion

One issue that remains a central challenge is the possibility of self-motion. Kant may seek no source for locomotion outside of nature , but one may wonder whether Kant can allow for any self-motion in material objects. In the pure mechanics of undifferentiated bodies, motion is primarily regarded as fundamentally external to matter. With inertia , any change in motion or rest of a material body is externally determined. Is there any hope of admitting into nature the apparent self-motion of living things in general and rational animals in particular? A preliminary answer may be gleaned by following out how Kant's treatment of the mechanics of bodies in motion proceeds from his account of the dynamics of matter.

Throughout *The Metaphysical Foundations of Natural Science* Kant relies upon the categories of pure understanding and the principles that correspond to them, which were developed in *The Critique of Pure Reason*. Whereas these categories and principles apply to objects of experience in general, pure mechanics concerns material objects. Dynamics provides an account of how space is filled, that is, an account of matter itself. Kant claims that dynamics determines matter in respect to the categories of quality: reality, negation, and limitation. [25] He associates reality with repulsion, negation with attraction, and limitation with the way in which both go together. Do these categories plausibly determine the features in question and provide for the mechanical interaction of bodies?

Kant's association of the category of reality with repulsion presumes, first, that one can consider repulsion by itself, and secondly, that repulsion by itself is sufficient to provide some determinate material being. The category of reality pertains generally to the presence of some determinacy. The category of negation, by contrast, pertains to the privation or absence of some determinacy. For repulsion to provide material reality, it ought to fill space by itself, but as Kant himself is compelled to acknowledge, repulsion cannot do that alone. By itself, repulsion converts into an instantaneous infinite dissipation indistinguishable from empty space.

Similarly, attraction by itself immediately collapses into a point, negating any filling of space. Only when repulsion and attraction combine can there be a determinate filling of space, with a limitation involving both reality and negation. That limitation is materially embodied in the filling of a limited space to a determinate degree or density . Mechanics depends upon this dynamic determinate filling of space, which constitutes matter through the combination of complementary moving forces of repulsion and attraction.

Since dynamics provides for determinate matter, it makes possible a plurality of bodies and the relations that they enter into as purely material entities. Insofar as mechanics concerns these relations, it should be no surprise that Kant develops his pure mechanics as exhibiting the categories of relation, shown to apply to objects of experience in general in *The Critique of Pure Reason*, as they apply to matter. These categories of relation all involve substances and one might ask what this signifies with regard to the character of the relations in question. Kant's conception of substance is very different from that of Aristotle , but is typical of how early modern thinkers think of substance. Whereas Aristotle conceives substance to combine matter with active form, early modern philosophers through Kant conceive substance as the substrate of accidents. The latter conception goes together with the whole way in which objectivity is determined by Kant and transcendental philosophy in general. Since transcendental philosophy determines objectivity in respect to the structure of knowing, which conditions all objects of experience in the same way, the only thing that can hold true necessarily of any object is what

holds true for them all, irrespective of what they are in particular. It follows that substances cannot have active forms that necessarily determine their alterations, but instead can have nothing but accidents, indifferent to what they are. There can be nothing necessary about the specific qualities that substances have. They cannot comprise determinate natures or essences in the sense in which form entails necessary features that allow for the deduction of specific differences from the genus or species being of an entity. With objects determined by the structure of cognition, which underlies them all, they may indeed have a substrate, but that substrate is the receptacle of features that are inherently contingent. One cannot know a priori what the features of a substance are, because they are not necessary to substance, but accidents, which, as such, can only be known empirically. What can be known a priori about substances are the relations they have to one another, provided these relations leave contingent their specific qualities. Insofar as the features of substance are accidents, that is, contingent, any changes of substance depend on something else rather than being determined by substance's specific nature . Since substance just has accidents, all alteration must take the form of externally determined change, indifferent to what cause and effect may be.

In the *Critique of Pure Reason*, Kant presents the category of substance as applying necessarily to all objects of experience. They must be substances, substrates of accidents. [26] Substance does not here give itself any determinacy. Rather, what pertains to it depends upon other things. Accordingly, there is a relation of substance and accident. With the category of substance Kant imposes that relation upon all possible objects of experience. All objects of experience are substances with accidents, subject to external determination.

Kant then adds something else in the second edition of the *Critique of Pure Reason*, the principle that the quantity of substance remains constant for objects of experience. [27] To support this principle, Kant maintains that we cannot have any unitary objectivity unless we can recognize there to be a persisting substrate underlying phenomena. Kant's argument does not make clear whether every individual object must have a substance whose quantity remains constant or whether it is just the aggregate quantity of substance in the totality of objectivity that must be conserved. In either case, the question remains as to how this quantitative constancy is to be observable.

Kant provides an answer to this in the *Metaphysical Foundations of Natural Science*, although, as he admits, this answer applies to physical objects, rather than to objects in general, which can supposedly include psychological phenomena as well as phenomena of "outer sense". In his Mechanics Kant reformulates the principle of constancy of substance in physical terms: namely, in all changes of corporeal nature , of material bodies, the quantity of matter taken as a whole remains the same. This does not mean that particular bodies must retain the same amount of matter. They can decompose or be recombined with other things, as in chemistry and life. What will have to remain unchanged is the total quantity of matter in the universe.

Kant presents three laws of mechanics, each specified in regard to a different category, and we need to examine how they embody these categories in specifically physical terms.

The First Law of Mechanics reflects the category of substance by dictating that "in all changes of corporeal nature the total quantity of matter remains the same, neither increased nor diminished". [28] As we shall see, this principle's embodiment of the category of substance has important ramifications for what changes physical things can undergo.

The Second Law of Mechanics embodies the second category of relation, which is that of cause and effect, mandating that "Every change in matter has an external cause", with the parenthetical clarification that "Every body persists in its state of rest or motion, in the same

direction, and with the same speed, if it is not compelled by an external cause to leaves this state". [29] Kant upholds this same category of causality in the Second Analogy of the *Critique of Pure Reason* by arguing that no events could count as objective unless their temporal sequence is a necessary succession. [30] Only when we can experience that a state of affairs necessarily follows from an antecedent state of affairs can we apprehend that the time order is not a subjective product of our imagination, but something objective. This is tantamount to acknowledging that the later state of affairs is caused by the state of affairs that precedes it. Kant's argument does not provide any particular linkage between a specific object in a certain state of affairs and any other particular object in the state that follows. Rather, all that is mandatory is that the whole preceding state of affairs be necessary for what follows. In this sense, all events, that is, all objective changes, must occur necessarily. The necessity in question can be nothing more than efficient causality, for it does not depend upon the particular nature that any of the objects in a state of affairs possess. If pertains simply to the objectivity of the temporal relation between states of affairs, no matter what kind of things are in play. This restriction of all objective process to efficient causality, endorsed by early modern philosophers through Kant and beyond, might appear questionable. It requires that nothing about the natures of the things comprising an antecedent state of affairs can influence what causal efficacy they will have. Knowing what they are will tell one nothing about what will follow from them. If it did, formal causality would play a role. Efficient causality, by contrast, is a relationship of cause and effect where the effect has nothing to do whatsoever with the nature of the thing that causes it. Such causality is neither formal nor teleological, but material and blind, since it pertains to things *qua* matter, irrespective of their form and import. All that can be said about this causality, at least as it is initially introduced in the *Critique of Pure Reason*, is that it determines the order of events in time to be necessary.

Here, in pure mechanics, the category of cause and effect applies to objects that are not just objects in general but material entities. Formulated as the second law of pure mechanics , the principle of causality now mandates simply that every change of matter has an external cause. Insofar as matter as matter is homogeneous, the only change it can undergo as such is in its place in space-time . The second law of mechanics is therefore nothing but the law of inertia and its corollary, that change in motion is relative to the moving force applied. Since the effects of moving force upon the acceleration of a body depend inversely upon that body 's mass , moving force will be relative to change in momentum, or moving force will equal acceleration divided by the accelerating object's mass . Accordingly, every material entity remains in its state of rest or constant motion unless compelled to alter that state by an external cause, consisting in a moving force. Changes in matter can only involve changes in spatiotemporal determination, which is indifferent to natural type (form) or ends. Such spatiotemporal alteration can comprise not just the locomotion of a body as a whole, but also its breaking apart or combination with other material. These decompositions and aggregations of matter do not violate the first principle of pure mechanics , of the constancy of the quantity of matter, for the total amount of matter remains the same. In every case, all that can happen to matter are spatiotemporal changes that are determined externally by some other body . The efficacy of that other body will itself result from some other matter in motion, whose own locomotion is equally determined from without.

Kant points out that the second law of pure mechanics, the law of inertia and force-induced acceleration , determines matter to be lifeless. [31] Matter is dead. It is devoid of any vitality, of any self-activity. Matter has no internal principle of change, such as Aristotle ascribes to natural substance, which he thereby treats as if it were alive. For Kant, the only kind of lawful change in

nature has to do with locomotion , insofar as dynamics and mechanics provide the only field for any a priori principles of physical reality.

The third law of mechanics provides one more a priori principle governing the interaction of bodies, mandating that “in all communication of motion, action and reaction are always equal to one another”. [32] This law applies to matter the third category of relation, the category of community or reciprocal influence. In the Third Analogy of the *Critique of Pure Reason* Kant presented the corresponding principle applying to all objects of experience: that any objects of experience that coexist must appear so as to be reciprocally influencing one another. [33] The rationale for this principle is that if coexisting objects do not appear to be mutually determining one another, then their simultaneous existence cannot be certifiably objective. Without some manifest reciprocal causal efficacy, there is no way to be certain that the order indifference in observing objects signifies that they do coexist. If the objects in a room coexist I can look at different parts of a room in any order I choose without altering what there is to see. Nonetheless, without mutual influence, the order indifference of what I observe cannot itself guarantee that the objects in question have actually been simultaneously present. Perhaps these objects do not enduringly coexist, but just pop into being when I turn my head in their direction and then cease to exist when I look the other way. Or they are just products of my imagination, which can imagine them in any order it chooses. If, however, they manifestly reflect the presence of one another no matter when and where I look at them, then their coexistence is something objective.

Here in mechanics this principle is applied to matter and one must consider what could possibly be the physical exemplification of the principle of community. The obvious candidate is universal gravitation, by which all material objects influence one another through their gravitational attraction, which extends infinitely and from which no thing can escape nor evade wielding in turn. All coexisting objects will exhibit this gravitational interaction in principle, even if calculating the effects in their entirety is an infinitely complex challenge. What will make manifest gravitational influence is the locomotion of bodies and this effect will be observable at least with respect to the nearest large bodies in the vicinity of any physical object.

Kant, however, does not offer universal gravitation as the physical realization of the category of community. Instead, he offers his version of Newton’s Third Law of Motion: that “in all communication of motion, action and reaction are always equal to one another”. [34] This principle will provide a necessary reciprocal communication of moving force that will supposedly materialize the category of community. Since the changes that bodies undergo qua matter are changes with regard to locomotion , the law of action and reaction will pertain to movement that is externally determined. With this principle, Kant presumes to have exhausted the a priori principles of mechanics.

It is worth noting, by way of anticipation, that in the final sections of his account of dynamics, Kant addresses aspects of matter that apply to relationships which Hegel will treat not in the context of the dynamics and mechanism of matter in motion, but in the subsequent context of the specifically physical determinations of nature . Kant here briefly considers differences in the cohesion of matter and the differentiation of gaseous, liquid , and solid states of matter . [35] These determinations go beyond dynamics and mechanics by introducing qualitative distinctions in material bodies to which the preceding principles are indifferent and which they leave undetermined. As we shall see, Kant is wary of offering any a priori necessary explanation of these physical phenomena.

Kant does follow his account of mechanics with a fourth and final section of his *Metaphysical Foundations of Natural Science,* but this section does not add any principles that

further concretize the nature of physical reality. The Kantian a priori account of nature remains restricted to the very sparse theory of dynamics and mechanics. The central pillar of this account is the concluding definition of matter presented as Explication 1 on page 536 of the original edition: “Matter is the movable insofar as it, as such a thing, has moving force”. [36] This definition is more than a merely dynamical conception. The dynamical consideration of matter concerns the determinate filling of space. Admittedly, Kant began by describing the filling of space as if it involves a body repelling other bodies from entering its place . This conception begs the question by presupposing material bodies and using a mechanical relation between bodies to account for matter. The filling of space must rather involve a self-repulsion as well as a self-attraction, which is something other than matter being the movable that exerts a moving force. The dynamical conception of matter can be at work with matter at rest and not wielding any moving force upon other bodies, leaving aside universal gravitation, which depends upon both self-repulsion and self-attraction. The dynamical concept concerns how matter fills its own space, not the derivative relation of how an extended body acts upon another extended body . The repulsion and attraction are self-related, consisting in self-repulsion and self-attraction. What is at stake is the real filling of space, which must be presupposed by any interaction of different bodies.

When different bodies are concerned, then repulsion and attraction are distinct in character. The mechanical repulsion of colliding bodies acts on contact, whereas the gravitational attraction of separate bodies acts at a distance, irrespective of anything in between.

5.3 Kant and the Problem of Determining Mass

The self-repulsion and self-attraction of matter provides for its quantitative determination as a determinate mass . The determination of mass , however, is exhibited in motion, which, as real, involves not just speed, but a quantity of moving force. The motion of a body combines mass with change of location over time . The standard mechanical expression for moving force is the product of mass and velocity.

How does one account for mass ? Has Kant explained what mass is? He does indicate that mass is the quantitative determination of matter, involving the number of movable parts in a determinate space. [37] That quantity builds mass to the extent that all its parts are regarded as simultaneously active or moving. In this respect, matter has mass insofar as it acts in mass , with all its parts moving in the same direction at the same time and thereby exerting a unitary moving force exhibiting the quantity of mass . In so construing mass , Kant is giving expression to how one can distinguish the unity of one body from another. In mechanics, the unity of a body is not determined just by spatial continuity. Whenever two bodies are in contact, their surfaces are just as much in direct connection as they are with their respective interiors. How then are they distinguished and what gives them their individual corporeal unity? It cannot consist in just extension or in the dynamic occupation of space through repulsive and attractive forces, since neither provides sufficient basis for differentiating contiguous bodies.

Instead, it depends on how all the parts of a body act together and impart a moving force as a whole. In this way, bodies in contact can oppose one another as distinct masses. To be one body , each must act as a unit, as *a* mass . Otherwise, their contiguous matter remains an uninterrupted continuum.

How then does the unity of a body express itself dynamically? Can it be an individual mass independently of its interaction with another body ? If all parts of some matter retain their common outermost boundary either at rest or in motion, do they belong to one body ? And if so, does this depend upon their attractive forces consolidating into a common center of gravity ? What of two bodies at rest that touch? Are they distinct thanks only to the force exerted at their point of contact by gravitational attraction, wielded from different centers of gravity ?

When Kant here considers separate masses, he is not really talking about gravitational attraction at all. The dynamic filling of space through attraction and repulsion provides the primary cohesion of each body , on the basis of which each exerts gravitational force throughout the universe. Nonetheless, when two bodies are in contact there is automatically a pressure exerted on their respective surfaces. This is because each has a center of gravity , to which its counterpart strives to move. On this basis, each exerts a moving force, which can be correlated with their respective masses. Kant speaks of the quantity of mass having to do with the number of the movable parts of matter that fill space. Yet how can the mass of bodies be distinguished by the number of their parts? Does the dynamic constitution of matter through repulsion and attraction allow for discrete parts of any determinate number? Or does it instead allow for all matter being infinitely divisible? Only if the force field of repulsion and attraction could somehow be converted into atomic particles or somehow bounded by nodal quanta intervals would the continuity of the dynamic material filling of space have any discrete parts or degrees.

Not surprisingly, Kant turns away from counting parts of matter to instead acknowledge, in Proposition 1, that “the quantity of matter, in comparison with *every* other matter, can be estimated only by the quantity of motion at a given speed”. [38] This raises the question, of course,

of how the quantity of motion at a given velocity can be determined. What is quantity of motion? The quantity of motion concerns the mechanical force wielded by the moving object.

The appeal to force seems readily workable, insofar as one equates moving force with the product of mass and velocity. As Hegel points out in his *Science of Logic* , force, however, has something very tautological about it. [39] Force is exhibited only in its effect on something else, that is, in its expression, consisting here in mechanics in the change in locomotion of some body . Is there any way to distinguish between force and its expression? What more can be said about force other than that it is exhibited in its effect, some change in the motion or rest of something else?

What then will be the quantity of motion? What is going to be the force that something has at a certain velocity? One will have to compare how different objects travelling at the same velocity impact upon the motion of other bodies, whose own quantity of motion has been determined in the same fashion. In each case, one needs to know not only the change in motion of an impacted body , but the quantity of motion, that is, the mass and force exhibited in the affected body ’s change. Unless the mass of the latter object can be independently determined, the quantities of motion of these mechanically interacting bodies cannot be established through the locomotive changes they together undergo.

Mass is a completely undifferentiated factor, like matter itself. Insofar as all matter has the same dynamic constitution, matter is homogeneous. Since mass involves how the matter of a body acts as one, it too is homogeneous. Mass is something attributable to all matter qua moveable and exhibited in all mechanical relations of bodies in motion. The homogeneity of mass is expressed, of course, in the quantifiable relation of mass to force and velocity. This homogeneity does not mean that all bodies have the same density . The same mass can be contained in different volumes, which will be exhibited in how bodies of the same extension and travelling at the same velocity have different impacts upon an object. Just as the motion of bodies is subject to continuous decrease or increase, so objects can exhibit densities of similarly different degrees in how they impact upon the motion of other bodies.

Mass and the quantity of motion give us the resources to address the first law of mechanics (“In all changes of corporeal nature the total quantity of matter remains the same, neither increased nor diminished”). [40] Now we have the means for giving the quantity of matter some definite measure. The quantity of matter will be exhibited in how the motions of bodies impact upon one another. On Kant’s account, these interacting motions should confirm the first law of motion, that in all change in nature , the quantity of matter will remain the same.

What does Kant supply as proof of this first law of motion? First of all, he has at his disposal the principles of “universal metaphysics ”, established in the *Critique of Pure Reason*, which govern all possible objects of experience. This “metaphysics ” provides synthetic a priori knowledge of phenomena, which allegedly are all that we can know with any universality and necessity. Kant’s “First Analogy” presents the “principle of the persistence of substance”, according to which, in the words of the second edition of the *Critique*, “In all change of appearances substance persists, and its quantum is neither increased nor diminished in nature ”. [41] Kant intends the universal metaphysics of experience of the *Critique of Pure Reason* to apply to possible objects of experience in general, and not specifically to things of material nature . Presumably, experience can involve non-material objects, such as psychological phenomena, although Kant himself does not show how the principles governing experience can be applied to those as well as physical phenomena. What happens, then, when we are dealing with substances that are material? How is the general metaphysical principle of the First Analogy to apply? What

is the substance in material nature that could remain constant and how is its conservation to be manifest? The substance in corporeal nature is the substratum of all the “accidents”, the contingencies that occur in physical reality. One could imagine that the accidents in question consist of changes in the spatiotemporal location of bodies, that is, in their motion. Such alterations would presumably leave the amount of material substance unchanged, so long as motion leaves mass unaffected. Of course, if mass altered in connection with motion, as Einstein’s theory of relativity might suggest, then the total mass of material substance would be conserved only if mass -altering motions inherently compensated any material losses with corresponding material gains. Alternately, one might imagine individual bodies to contingently decompose into or arise from the combination of other materials while maintaining the total amount of material substance in nature . Finally, material bodies could perish into or come to be from immaterial energy and still conserve the total quantity of material substance provided each perishing was matched by a quantitatively equivalent emergence of matter. In all these cases, what would manifest the amount of material substance would be the relation of mass and motion to force as exhibited in the mechanical and gravitational interactions of bodies. [42]

Does Kant provide any argument to justify the conservation of the total of material substance other than invoking the general metaphysical principle of the First Analogy? Insofar as the quantity of material substance, or matter, becomes measurable through moving force, does the constancy of matter translate into a conservation of the total amount of moving force, which may be communicated, but not diminished? If the amount of moving force in nature remains constant, what does that imply? Does it contradict entropy and the thermodynamic principle of the dissipation of kinetic energy ?

Would it be possible for the total quantity of matter to be preserved, but for everything to come to rest? Without motion and moving force, would the quantity of matter have any determinable measure? The quantity of matter is manifest not only in the mechanical interaction of impacting bodies, but in gravitational attraction, which Kant recognizes to be proportional to the mass and inversely proportional to the square of the distance of bodies. [43] Insofar as the dynamic account of matter entails attractive and repulsive forces that together engender the gravitational attraction of separate bodies, all bodies could come to rest in only one way. They would have to all conglomerate around the same center of gravity in one contiguous sphere, whose own occupation of space would depend upon the combined gravitational compression not overwhelming the repulsive forces constitutive of matter, let alone triggering nuclear fusions that would disrupt the immobility of the compressed matter.

It is, of course, doubtful, that such a condition could allow for life, let alone, any rational inquiry into nature . Granted that bodies are at a distance from one another and subject to changes in spatiotemporal position, gravitational attraction will be manifest in the motion of bodies in relation to the quantity of their masses. The amount of material substance of a body will be exhibited in the gravitational force it wields upon other bodies and how that force affects their motion as well as its own. Unlike the mechanical interaction of bodies that depends upon impact , gravitational relations will affect the motions of bodies at a distance, including before and after contact with one another. The results of mechanical impact and communication of motion will have to be taken into account together with gravitational effects to accurately measure the quantity of matter involved. Gravity operates at a distance under all circumstances, including weightlessness, where weight is suspended due to the equalization of opposing gravitational forces or of gravity and mechanical forces of acceleration . Consequently, the quantity of matter will be ubiquitously on display in the motion of bodies in respect to

mechanical and gravitational forces. Of course, if further forces come into play in nature , such as electromagnetic forces and the self-motions of living organisms, these too will have to be taken into account in considering how any conservation of matter can be quantitatively realized.

Although gravitational attraction depends upon the combination of attractive and repulsive forces that allows for bodies in the first place , its operation might seem to involve an exclusive working of attraction that would ultimately collapse all matter into one great black hole unless some other repulsive force intervenes. [44] The mechanical interaction of bodies provides elements of a resistance to such a collapse in the inertia of bodies and particularly in the third law of motion, which mandates equal action and reaction. With action and reaction, impact , whereby bodies make contact, equally involves repulsion.

It is important to consider to what degree the laws of motion, taken over by Kant from Newton , abstract from gravity and whether they are compatible with or opposed to gravitational attraction. The quantity of material substance manifests itself in how the moving force of one body alters the motion of another body . This will be exhibited whether the motions involve gravitational attraction or body impacts associated with action and reaction.

The second law of motion is a law of inertia mandating that every change in the spatiotemporal determination of matter has an external cause. [45] To treat change in motion as external to material bodies is equivalent to treating them as inertial. As inertial, every material body remains in the same state of rest or motion unless it is acted upon by some other body , whose moving force puts it into motion, changes its velocity and perhaps its direction, or brings it to a halt. To support this law, Kant draws once more upon the universal metaphysics of experience, which has mandated that every alteration in objects of experience has a cause residing in some other state of affairs. Since this law applies to objects of experience no matter what they are, it applies to them qua matter, with indifference to their specific form. In other words, this law of causality is a law of matter, and changes in matter, without regard to form, pertain to nothing other than location in space and time . The changes in location are external to the objects that undergo them since efficient causal efficacy has nothing to do with what an object is. It is something imparted upon objects from without, through nothing other than material changes to which some other objects have become subject due to some other external cause. Once again, Kant is concretizing his universal metaphysics of experience, according to which every change pertaining to possible objects of experience has a cause. Here, the objects in question are restricted to non-psychological, that is, physical phenomena. The universality of causal determination must be applied to the type of change that is specific to material things—namely, changes in spatiotemporal position, which, as such, are indifferent to everything else about the body in question. Kant's proof of the second law of motion basically consists in explicating how the general law of causality pertains to bodies, that is, objects with matter. [46] What does it mean for bodies to undergo changes that are caused by some other material body ? The changes that pertain to bodies as such consist in alterations with regard to motion: passing into motion from rest, coming to rest from motion, or accelerating or deaccelerating motion without coming to rest.

As the second law of motion attests, matter has no internal grounds for causal determination. Matter, broadly speaking, does not move itself. It is inert, lifeless. The law of inertia , the second law of motion, signifies that matter is lifeless, that it is not self-moving. Although a body may remain in constant motion if no external force is applied to slow or accelerate it, a body could just as well be at rest if no force had set it in motion in the first place .

Does this inertial character of matter follow from its dynamic constitution out of attractive

and repulsive forces? Matter, as that which fills space to the exclusion of anything else, minimally has nothing more to it than the conjunction of these forces, by which a material body can occupy some place in time . Attraction and repulsion do not entail any further alterations, let alone any relations to other bodies other than mutual exclusion from one another's spatial-temporal domains.

Matter, however, entails gravity to the extent that the attractive and repulsive forces constituting bodies equally subjects them to an attractive force that is relative to the mass each body has and disperses itself from the center of each body in accord with how it is distributed in the expanse of space, whose surface grows larger in proportion to the square of the distance of its radius. The mass of each object is determinable by the force it exerts in altering the motion of other objects. Does the relation of gravitational attraction to mass reflect how the mass of an object is not a function of the space it occupies but of the force of the attractive and repulsive forces by which it excludes other bodies from its space-time location? In other words, objects may have equal volumes but different densities, and these densities may exhibit varying dynamic forces. Accordingly, a body with a greater attractive force may wield greater gravitational attraction upon other bodies, provided its greater repulsive force does not act beyond its surface. If its attractive force acts at a distance disseminating from the center of the body in question, then that force, whose magnitude is relative to the mass of the object, will be distributed on the surface of the sphere that would be constructed with a radius equal to the object's distance to whatever it attracts gravitationally (and vice versa). Insofar as the area of the surface of a sphere = $4\pi r^2$, the resulting distribution of gravitational attraction is governed by the inverse square rule, where the gravitational attraction between two objects equals the sum of the mass of the attracting objects divided by the square of their distance from one another.

Does gravitation undermine the laws of inertial mechanics? Or do these laws supplement the effects of gravitation, which may be comparatively imperceptible in small scale interactions? In distinction from the attractive force that counteracts repulsion to enable matter to occupy space, gravity acts between distinct bodies, with separate centers of gravity . As such, the gravitational force that emanates from a body does not produce any alterations in that body , taken by itself. A body 's own gravitational attraction does not alter that body 's position and trajectory in space time unless some other body or bodies come into play. In this respect, the second law of motion, the law of inertia , remains unperturbed by gravity , *if* a body is regarded in isolation. If, however, bodies are not alone, then inertial effects will be conjoined with gravitational interaction. The presence of a body in space and time is, however, not a unique natural actuality, but a contingently given actuality, whose multiplicity is left undetermined by space, time , and the constitution of matter itself. Consequently, nature will contain a contingent multiplicity of bodies in contingent locations. The laws of mechanics will thus operate alongside gravity and there is nothing in their operation that prevents them from being simultaneously operative.

In other words, although bodies will move one another through gravitational attraction, laws of inertia will still apply to them. These rudimentary aspects of matter and motion all pertain independently of the further natural relations of positive and negative electromagnetic forces, without which light and the relativistic relationships that involve light, cannot be nor be conceived. As we shall see, only when electromagnetic forces constitute chemical reactions, and these become contingently coordinated to form self-sustaining organisms, will bodies become self-moving, in addition to being subject to gravity and inertia .

Aristotle cannot comprehend how bodies in general can remain at rest or continue in constant unidirectional motion without a force continually being applied to them. Although bodies of a

certain kind may gravitate to their natural place , something must account for their being elsewhere. And since Aristotle , like Kant, precludes self-motion, even “natural” motion depends upon a mover. Kant does not invoke a force of inertia . Rather, the second law of motion entails that inertia operates without any force and only gives way when an external force is applied to a body , altering its state of rest or its state of constant motion.

In upholding the second law of motion in conjunction with the general metaphysical principle that all occurrences are caused, Kant must consider change of position without change of speed as not being an occurrence requiring a cause. If the orbit of planetary bodies were perfectly circular and uniform in speed, as Aristotle tends to assume, they might seem to be candidates for inertial motion, if the continual, but constant, change in direction were not considered an event requiring causal explanation. By contrast, if solar systems are governed by the elliptical motions of varying speed specified by Kepler’s laws of planetary orbits, gravitational forces must be invoked.

Where motions are determined by the application of force, Kant acknowledges, motion loses the relative character that it retains when inertia is all that is in play. In cases of rest and uniform motion, Kant notes, there is no difference in attributing motion to one body as opposed to others. When, however, mechanical interaction is at play, with force, mass , and acceleration at work, it is no longer a matter of indifference whether we consider one object to be moving rather than another. [47] This difference is of central significance in considering the third law of motion, of equal action and reaction.

5.4 Mechanics and Absolute Motion

Kant maintains that the investigation of pure mechanics , of the universal necessary laws of matter in motion, is not identical with the investigation of objects of knowledge in general, since matter is something empirical. Material things are a particular type of object of experience. They are objects that are spatially as well as temporally sensible and not just psychological, merely temporally sensible. Nonetheless, despite Kant's assurances to the contrary, matter is not something merely empirical within the Kantian framework. Matter is inescapably present in any experience, since, as Kant's own "Refutation of Idealism" underscores, there can be no inner experience of psychological phenomena without outer experience of physical, spatial objects, which must be material to be spatially perceivable. [48] Only awareness of physical objects in space allows for any perception of time , without which no experience of any kind is possible. Accordingly, the account of material objects that Kant provides in his *Metaphysical Foundations of Natural Science* can retain an a priori character as an explication of what is already implicit in the *Critique of Pure Reason's* general metaphysics of possible objects of experience.

In this respect, the third law of motion, of equal action and reaction, can be considered an explication of the principle of Kant's third analogy of experience, that co-existing objects are in a community of mutual influence. Kant himself never attempts to apply any of his analogies of experience to psychological phenomena. All his illustrations for the analogies in the *Critique of Pure Reason* concern material things. This is true of the first analogy, concerning how the category of substance applies to objects of possible experience, of the second analogy, concerning the application of the category of causality to objective occurrences, and of the third analogy, concerning the application of the category of community to coexisting objects of experience. In each case, matter in motion is invoked to give perceivable exemplification of the principle at stake. The permanence of substance is illustrated by the constancy in the quantity of matter in nature . Causality is illustrated by mechanical alterations in the motions of objects. Community, finally, is illustrated by reciprocal material alterations, which, as indifferent to the specific nature of the co-existing objects, involve correlated simultaneous locomotions.

Kant is content to tie coexistence to the action and reaction mandated by the third law of motion, but one might wonder whether it is sufficient to supply the bond of mutual influence that should apply to *all* coexisting objects. Action and reaction applies to a pair of moving objects, whereas the requirement that all coexisting objects of experience manifest their simultaneous presence applies not just to separate pairs of things, but between all such pairs, as well as between all objects that might not be subject to any mechanical impacts. What better supports the community of all of physical nature at any time is universal gravitation, whereby every material body exerts gravitational force upon every other. Admittedly, calculating the effects of gravitational attraction may become unworkable as the number of bodies increases. Nonetheless, in principle the motions of all bodies should manifest the gravity that extends throughout the universe, even though other forces and self-motions may supplement its effects.

What then provides justification for the third law of motion, either as an explication of the principle of community or as immanent to material nature , given the dynamic constitution of matter and the first two laws of motion? The third law presents a communication of motion, where action and reaction of objects are to always equal one another. Action will be reciprocated by reaction, where the actions in question are motions. As action and reaction, these motions are inherently related to one another. Do they involve a communication of motion, where reaction

follows action, rather than being simultaneous? Does the simultaneity of co-existence then make itself present in that action and reaction involve a contact between bodies in relative motion , where they share the same boundary in space time when and where their impact occurs? And how is the equality of action and reaction to be determined?

The situation of action and reaction can be variously described. It can be portrayed as one object being at rest relative to another, whose movement communicates motion to the object at rest relative to it. The same situation can equally be described such that both objects are moving to one another at different speeds, whose difference is equivalent to the speed attributed to a moving object that approaches another at rest in the former scenario. It can also be characterized such that the object previously described as impacting upon its stationary counterpart is instead at rest and approached by the other body . What matters is the difference in their respective motions and the moving forces involved.

The equivalence of action and reaction is measured by the quantity of moving force of each, which is a function of both mass and velocity. Accordingly, if something of modest mass collides at great speed with something of gigantic mass , the latter will react with a relative movement of a comparatively very low velocity.

The operation of equivalent action and reaction operates independently of to what degree the bodies in question are subject to compression and elasticity that would absorb and repel the moving force to which they are subject. The dynamic conception of matter and the three laws of motion do not themselves provide much to account for differences in the cohesion and elasticity of bodies. The latter depends more directly upon the electromagnetic polarities and the molecular and crystalline compositions they make possible, as well as upon the phase differences of solid , liquid , gas , and plasma . In any case, it can be presumed that the moving forces of action and reaction will maintain their equivalency in and through whatever compressions and elastic expansions bodies undergo.

Granted the equality of moving forces, can the reaction occur instantaneously upon impact ? In face of this question, Kant introduces a “mechanical” law of continuity [49] reflecting the analogous principle of the continuity of change for any possible objects of experience that he inserted in the discussion of the Second Analogy in the *Critique of Pure Reason*. [50] Aristotle had regarded locomotion to be continuous, but regarded the other kinds of change to be discontinuous. [51] When Kant identifies changes in objects of a possible experience, those that are objective and therefore causally determined consist in nothing but locomotion or the related kinetic motion associated with temperature change. Here in the mechanics of matter, of course, action and reaction concern moving forces and the locomotions to which they are connected. Applied to material bodies, the continuity of change involves nothing but the continuity of motion. How does this apply to action and reaction?

If objects collide travelling in opposite linear paths, the continuity of change of motion will entail that the effect of moving forces will not be instantaneously produced, but will gradually generate the alteration in movement. There will be some period during which the accelerations and corresponding de-accelerations will build. Similarly, if objects collide at an angle, their change of direction will not occur immediately, but take some time to occur. In each case, there will be equal action and reaction, but the action and reaction will gradually build to a certain level, exhibiting the entire moving force.

The ground for this continuous, gradual alteration in motion is the presumption by Kant that bodies will not be absolutely rigid. If objects were absolutely hard, containing repulsive force not just counteracting the body ’s own attractive force, but strong enough to resist any other moving

force, then action and reaction would instantaneously communicate themselves. There would be no compression and rebound of any sort and changes in velocity and direction would be immediate.

Kant's dismissal of infinite rigidity is rooted in his understanding that the dynamic constitution of matter leaves matter always relatively penetrable, rather than absolutely impenetrable. [52] The repulsive force of a body is sufficient to counteract the attractive force it contains, but the body surface will yield to additional external force that overcomes that balance. Nonetheless, matter cannot be compressed to a point and vanish, which, after all, would violate the conservation of matter . If matter and energy were convertible, then matter could be reduced to a "black hole", or rather a "black point", containing equivalent immaterial energy . Kant, however, presumes that as matter is compressed, its total repulsive force does not diminish. Since matter consists in nothing but the conjunction of attractive and repulsive force fields, the conservation of matter entails that such forces are themselves conserved. Consequently, as the surface area of the compressed body decreases, the force of resistance per surface area increases. Thus, as the compression of matter approaches a point, the repulsive force on its infinitesmal surface approaches infinity, defeating any force that would destroy a body 's filling of space. [53]

This is what allows the balance of attractive and repulsive force to resist a destruction of material extension the moment repulsive force becomes less than the forces opposing it. Any overpowering of repulsion leads to compression, increasing the amount of repulsive force on each quantum of surface area. Annihilation is prevented because the increase in repulsive force on each surface area is not balanced by a greater increase in attractive force. Although repulsive force does extend throughout the volume of the body , it does not extend beyond the surface. By contrast, the force of attraction operates at a distance and has a fixed quantum related to the mass of the body . A body 's attractive force diminishes in relation to the surface area of the sphere projecting beyond it to whatever is an object of its attraction. The contraction of the body , does not however, increase its attractive force, which remains relative to its mass .

Since bodies are susceptible to compression, but not to compressive annihilation, the impact involving action and reaction will necessarily exhibit a continuous, rather than discontinuous, acceleration and de-acceleration of the colliding bodies. This necessity follows from the dynamic character of matter.

Action and reaction will be further qualified by another factor ingredient in matter—gravitational attraction. Although either action and reaction or universal gravity might exemplify the "community" of "mutual influence" that Kant's universal metaphysics imposes upon possible objects of experience, they can be seen to operate together. The forces in question may be vastly different depending upon the masses of the colliding bodies and the bodies nearest them. As we shall see, these questions of scale will have important ramifications for the settings of various natural processes, including the different forms of motion. The distinguishing of motions that Aristotle distributed between celestial and terrestrial domains will resurface in somewhat different form in due consideration of the interaction of the different forces that are constitutive of matter.

At face value, gravity might appear to contradict the laws of inertia since bodies will always be exerting attractive force upon one another, no matter what their relative locations may be. A body at complete rest or in absolutely constant motion could only remain in such a state if all other gravitational forces counterbalance one another. Otherwise, gravitational attraction will entail acceleration or de-acceleration , however minute it may be. Nonetheless, the laws of inertia need not contradict gravity . They may abstract from gravity , but this simply signifies that they

involve relations of their own to which gravity itself applies in its universal reach. Consequently, the laws of inertia operate not in conflict, but in conjunction with gravity . Gravitation supervenes upon inertial motion by adding forces that are inherent in the coexistence and interaction of individual bodies. Although gravitational forces may be determined by the distance and mass of attracting bodies, their impact upon their movement can still involve inertial relations.

Notes

1. For a detailed account of this argument, which Hegel lays out in the opening sections of his *Science of Logic*, see Richard Dien Winfield, *Hegel's Science of Logic: A Critical Rethinking in Thirty Lectures* (Lanham, MD: Rowman & Littlefield, 2012), pp. 47–88.

2. Aristotle , *Physics*, Book V, Chap. 2, 226a23–35, in *The Complete Works of Aristotle* , I, p. 382.

3. Aristotle , *Physics*, Book VII, Chap. 2, 244b2–245a16, in *The Complete Works of Aristotle* , I, p. 411.

4. Aristotle , *Physics*, Book VIII, Chap. 7, 260b1–14, in *The Complete Works of Aristotle* , I, p. 435.

5. Aristotle , *Physics*, Book VIII, Chap. 7, 260a27–260b4, in *The Complete Works of Aristotle* , I, p. 435.

6. Aristotle , *Physics*, Book VIII, Chap. 7, 260b20–25, in *The Complete Works of Aristotle* , I, p. 435.

7. Aristotle , *Physics*, Book VIII, Chap. 7, 261a32–261b7, in *The Complete Works of Aristotle* , I, pp. 436–437.

8. The basis of this assumption is developed in Aristotle , *Physics*, Book VIII, Chap. 5, 256a4–258b9, in *The Complete Works of Aristotle* , I, pp. 427–432.

9. Aristotle , *Physics*, Book II, Chap. 1, 192b14–15, in *The Complete Works of Aristotle* , I, p. 329.

10. Aristotle , *Physics*, Book VII, Chap. 1, 241b34–243a31, in *The Complete Works of Aristotle* , I, pp. 407–409.

11. Aristotle , *Physics*, Book VII, Chap. 1, 241b36–242a49, in *The Complete Works of Aristotle* , I, p. 408.

12. Plato , *Republic*, 430e–431a, in Plato , *Complete Works*, ed. John M. Cooper (Indianapolis: Hackett, 1997), pp. 1062–1063.

13. Aristotle , *Politics*, Book I, Chap. 1, 1252a16–17, in *The Complete Works of Aristotle* , I, p. 1986.

14. Aristotle , *De anima*, Book III, Chap. 5, 430a10–19, in *The Complete Works of Aristotle* , I, p. 684.

15. Aristotle , *Metaphysics* , Book XII, Chap. 7, 1072b14–1073a13, in *The Complete Works of Aristotle* , II, p. 1695.

16. Aristotle , *Metaphysics* , Book XII, Chap. 7, 1072b1–3, in *The Complete Works of Aristotle* , II, p. 1694.

17. Aristotle , *Physics*, Book VIII, Chap. 9, 265a11–27, in *The Complete Works of Aristotle* , I, pp. 442–443.

18. Aristotle , *Metaphysics* , Book XII, Chap. 7, 1072b3–10, in *The Complete Works of Aristotle* , II, p. 1694.

19. Aristotle , *Physics*, Book VII, Chap. 1, 241b36–242a49, in *The Complete Works of Aristotle* , I, pp. 407–408.

20. Aristotle , *Physics*, Book V, Chap. 2, 225b–226a16, in *The Complete Works of Aristotle* , I, pp. 381–382.

21. Aristotle , *Physics*, Book VII, Chap. 2, 243a17–18, in *The Complete Works of Aristotle* , I, p. 410.

22. Aristotle , *Physics*, Book VII, Chap. 2, 243b17–244a4, in *The Complete Works of Aristotle* , I, p. 410.

23. In this respect, Einstein notes that classical (Newtonian) mechanics mandates the law of inertia under the condition where gravitational attraction between bodies is negligible, that is, where bodies are sufficiently small and distant that they can remain at rest or continue moving uniformly in a straight line. See Einstein, *Relativity: The Special and General Theory*, p. 80.

24. Aristotle , *On Generation and Corruption*, Book II, Chap. 10, 336b4–10, in *The Complete Works of Aristotle* , I, p. 551.

25. Kant, *Metaphysical Foundations of Natural Science*, "General Note to Dynamics", 523, pp. 61–62.

26. Kant, *Critique of Pure Reason*, A182, p. 299.

27. Kant, *Critique of Pure Reason*, B224, p. 299.

28. Kant, *Metaphysical Foundations of Natural Science*, 541, p. 80.

29. Kant, *Metaphysical Foundations of Natural Science*, 543, p. 82.

30. Kant, *Critique of Pure Reason*, A189/B232, p. 304.

31. Kant, *Metaphysical Foundations of Natural Science*, 544, p. 83.

32. Kant, *Metaphysical Foundations of Natural Science*, 544, p. 84.

33. Kant, *Critique of Pure Reason*, A211/B256, p. 316.

34. Kant, *Metaphysical Foundations of Natural Science*, 544, p. 84.

35. Kant, *Metaphysical Foundations of Natural Science*, 525–535, pp. 64–74.

36. Kant, *Metaphysical Foundations of Natural Science*, 536, p. 75.

37. Kant, *Metaphysical Foundations of Natural Science*, Explication 2, 537, p. 76.

38. Kant, *Metaphysical Foundations of Natural Science*, 537, p. 76.

39. Hegel, *Science of Logic*, pp. 518–523.

40. Kant, *Metaphysical Foundations of Natural Science*, 541, p. 80.

41. Kant, *Critique of Pure Reason*, B224, p. 299.

42. Einstein notes that before the Special Theory of Relativity, physics recognized the law of conservation of energy and the law of conservation of mass as two separate independent laws. With the Special Theory of Relativity formulating the equivalence of matter and energy ($E = mc^2$), these two laws of conservation become united into one law. See Einstein, *Relativity: The Special and the General Theory*, pp. 51–52.

43. As Einstein notes, “the same quality of a body manifests itself according to circumstances as ‘inertia ’ or a ‘weight’”, for “the *gravitational* mass of a body is equal to its *inertial* mass ”. See Einstein, *Relativity: The Special and the General Theory*, pp. 73–74.

44. Einstein points to this problem as a cosmological difficulty of Newton’s theory of gravitation, contradicting the observed distribution of matter in the universe. See Einstein, *Relativity: The Special and the General Theory*, pp. 119–120.

45. Kant, *Metaphysical Foundations of Natural Science*, 543, p. 82.

46. Kant, *Metaphysical Foundations of Natural Science*, 543, p. 83.

47. Kant, *Metaphysical Foundations of Natural Science*, 545–546, pp. 85–86.

48. Kant, *Critique of Pure Reason*, B274–276, pp. 326–327.

49. Kant formulates “the mechanical law of continuity (lex continui mechanica) as follows: in no body is the state of rest or motion, or the speed or direction of the latter, changed by impact instantaneously, but only in a certain time , through an infinite series of intermediate states, whose difference from one another is less than that between the first state and the last.” See Kant, *Metaphysical Foundations of Natural Science*, 552, p. 92.

50. Kant, *Critique of Pure Reason*, A208–209/B253–254, p. 315.

51. Aristotle , *Physics*, Book VIII, Chap. 7, 261a27–39, in *The Complete Works of Aristotle* , I, p. 436.

52. Kant, *Metaphysical Foundations of Natural Science*, Explication 4, Remark 1, 502, p. 39.

53. Kant, *Metaphysical Foundations of Natural Science*, Proposition 3, Proof, 501, p. 38.

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6. From Relative to Absolute Mechanics

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Aristotle , Kant, and Hegel provide accounts of the entirety of motion that present contrasting frameworks, involving different arrays of natural processes. Their conceptions may appear to be mutually exclusive, but it is worth investigating to what degree they can complement one another and contribute to a more inclusive, comprehensive treatment of motion in nature .

6.1 Implications of Aristotle ’s Account of Motion

In this connection, it is important to remember that fundamental to Aristotle ’s account of motion is the rejection of any self-motion. Aristotle regards it to be unintelligible for anything that is in motion to move itself. He gives a variety of arguments to support this view and on the basis of these arguments he maintains that there must be some source of motion outside of what is movable, something that sets something else in motion without itself moving or being moved. To be movable, something must occupy space and be able to change its location from one place to another. To do so something must have parts and thereby have a determinate magnitude. Hence, the source of motion must be devoid of parts and of magnitude, making it insusceptible of moving or being moved, and yet somehow it must still originate motion. [1]

Moreover, the source of motion for what is movable must operate continuously. If instead, the source of motion were to begin or cease imparting motion at some time and place , it itself would be undergoing a change, making a transition from a state of not imparting motion to one of moving something else or from a state of imparting motion to one of no longer doing so. The ultimate source of motion cannot itself be in motion if nothing is self-moving, for the supposed source of motion could only be in motion if moved by something else, forfeiting its position as originator of motion. [2]

Accordingly, the existence of any motion requires an unmoved mover that continuously generates motion. Motion in Aristotle ’s account pertains to alterations of any sort, not just alterations in spatial-temporal position. Although Aristotle hardly reduces all change to locomotion , he does characterize the continuous generation of motion by the unmoved mover as a generation of eternal, continuous locomotion . Such locomotion is circular in character, since circular motion uniquely has no determinate beginning or end and alters its direction in an unchanging, constant manner. Only this continuous, unchanging type of movement can be the product of the eternal unchanging unmoved mover. It follows that in order for the generation of eternal circular locomotion to be the ultimate source of all change in nature , all other forms of alteration must depend upon locomotion for their own origination, even if they are not reducible to spatial-temporal change.

Aristotle secures the primacy of locomotion upon its exclusive continuity, which allows it to follow directly from the eternal unchanging moving of the unmoved mover. Alteration cannot be continuous because it involves change from one contrary to another. Change in magnitude cannot be strictly continuous either because, although mathematical quantity may be continuous, substances that have magnitude have a determinate measure, which, once overstepped, causes those substances to forfeit their qualitative character. At the nodal point at which measure is breached, change in magnitude becomes qualitatively discontinuous. [3]

Locomotion may be continuous, but circular and linear motions differ in how their continuity proceeds. Circular motion is the only motion that does not have a beginning or middle or end and in that sense its continuity is endless. Linear motion may go on indeterminately, but it has a starting point which is not retraced, let alone, retraced without end. [4] Curvilinear, as opposed to circular, motion similarly lacks continuous repetition of the same manner of locomotion . This is true not only when curvilinear motion follows a path that never returns to its point of departure (as in parabolic trajectories), but even when curvilinear motion recurs in the manner of elliptical movement. Although it may then retrace its circuit, that non-circular circuit has an irregular curvature that renders its locomotion inconstant.

Aristotle does point out that one might imagine a plurality of unmoved movers, but he rejects any plural sources of motion. Although all motion could seem to be generated equally by one or many unmoved movers, Aristotle insists that the continuity of motion requires that its source be one and eternal. [5] The problem is not just that a plurality of unmoved movers might conflict with one other's generation of motion and thereby subject one another to change. More daunting is the very possibility of individuating unmoved movers. The unique exclusivity of a one and only unmoved mover is inescapable if one considers the difficulty of distinguishing one unmoved mover from any other. Lacking matter, as well as any determinate place , the unmoved mover has no other determinacy than its self-thinking thought. Self-thinking thought, as fully actual, eternal, and unchanging, has nothing to distinguish it from self-thinking thought per se. Consequently, nothing is available to differentiate one self-thinking thought from another self-thinking thought. An unmoved mover is and can only be one.

The exclusivity of the unique unmoved mover could not be challenged by the motions of things that are moved. How, for example, might one attribute the motion of some celestial sphere to one unmoved mover as opposed to another? Could differences in velocity, radii, or inclination entail that celestial motions must have different sources? And if so, how could the motion of one celestial sphere be tied to one unmoved mover as opposed to any other?

A similar difficulty applies to problems of individuating disembodied souls. Doctrines of metempsychosis may assume that the same soul is reincarnated in successive bodies, but how can any embodiments be attributed to the same soul? Just as Kant's "I" that can accompany all my representations has nothing to individuate it from the "I" of any other consciousness , so the disembodied soul of metempsychosis has nothing that can tie it to any particular body or succession of bodies.

The situation is different when particular motions have their source in moving forces operating in determinate locations. Then, an individuated mover comes into identifiable contact with what it moves. This situation pertains to how the eternal circular motion of the celestial spheres imparts irregular motion to terrestrial things. Even though a celestial sphere may be rotating endlessly at a constant velocity, there are still variations in speed as one moves to and from the circumference of the rotating celestial sphere. The rotation is fastest on the circumference itself, and this distinction, combined with the irregularities of contact due to inclination, allows for the generation of irregular changes. Given the plurality of terrestrial things with different natures, the intermittent communication of celestial motion could provide both discontinuous alteration and change of magnitude.

Aristotle does point out that there are those who question the need for an unmoved mover by pointing to animals, such as ourselves, who move themselves from a state of rest. Why cannot the whole universe then move itself like an animal? Aristotle disputes this objection by arguing against self-motion in animals. He points out that animals only appear to move themselves on the basis of obtaining nutrition from their environment, which sets both their desires and bodies in motion, and even makes it possible for our reason to operate. Hence, when animals seem to move themselves, their movement is really dependent upon motion from without, which causes one part of the animal body to move other parts, maintaining the separation between what causes and what suffers motion. [6] If we try and bring all these individual motions back to circular eternal motion, we somehow must show that it activates some potential within animal organisms. What their forms are and why they exist is something for which the unmoved mover can offer no explanation. Instead of accounting for why the cosmos is the way it is, the unmoved mover can only secure that it moves.

The forms of natural entities are not themselves caused. They do not come to be or perish. Individual substances may arise and pass away to the extent that forms become embodied in or disembodied from matter. Artifacts may be manufactured and living things may be born. Can these changes by derived from the eternal circular motion of celestial bodies?

Any such derivation must somehow cope with the limitation that it must operate with a nature in which, on Aristotle ’s account, inertia and gravity are absent. By itself, inertial movement provides no explanation for how things come to be at rest or in accelerated motion. Leaving matter and motion external to one another appears to render motion in need of a source outside of matter as a whole. Gravity , however, removes the need for an immaterial unmoved mover by placing within matter a source of motion, given the plurality of bodies in different locations.

Aristotle attempts to explain away the appearance of inertia in Chap. 10 of Book VIII of the *Physics*. [7] He there considers the common occurrence where a mover imparts motion to a material substance that then continues in motion after the mover is no longer in contact with it. Such phenomena can readily illustrate inertia , but Aristotle cannot accept inertia any more than he can accept universal gravity . Kant associates inertia with the lifelessness of matter, from which self-motion must be accordingly excluded. This exclusion might seem to put Kant in the company of Aristotle , whose rejection of self-motion ushers in the need for an unmoved mover. Aristotle , however, cannot accept inertia if the motion of bodies is at all connected to what they are. Inertia , which sets motion external to material substance, leaves matter subject to nothing but material, efficient causality, which applies to things indifferently to what they are. Aristotle , however, ties place to the form of material substance, which means that different types of matter will gravitate naturally to distinct locations, rather than be in places due to forces applied from without.

How then can Aristotle explain the commonplace phenomenon of material substances remaining in motion after losing contact with objects that have set them in motion? Aristotle appeals to another, unnoticed mover, namely air that comes in between the original mover and the moved and continues pushing forward what was set in motion through the earlier manifest contact. The pushing air will be in continuous contact with the air in front of it, through whose intermediary impulse, the moving object will remain in motion after the original contact with some more tangible mover has been broken. [8] If, however, an object had been propelled into outer space beyond the terrestrial atmosphere, Aristotle would have to expect the material substance’s motion to cease, abstraction made of that substance’s trajectory in search of the place to which it naturally tends, unless other movers impede its natural course.

Aristotle claims that there is no way in which anything but an unmoved mover could impart unchanging continuous motion. Now why cannot eternal circular motion impart motion like itself? To begin with, any individual substances that are not eternal can hardly move endlessly. What about other celestial bodies, which Aristotle considers eternal? Could one celestial body impart eternal motion to another celestial body if for some reason they were to make contact? Such contact cannot move eternally, however, unless it is itself continuous without any beginning or end. Only bodies that are eternally conjoined could move together forever, but then can one distinguish which is pushing and which is pulling? Or rather, are both being moved together by the unmoved mover, rather than by one another? If they come into contact with one another after being apart, then not every part is going to make contact at the same time and the ensuing motion will not be unitary or continuous, unless each object is infinitely rigid. Hence, even when celestial bodies collide, Aristotle would have to expect variable locomotions

resulting, including linear and unevenly curvilinear movements, as well as circular revolutions that are not unending. Moreover, if celestial motion is to affect other material substances through contact, something must propel terrestrial objects to the heavens. Yet if the unmoved mover originates motion by moving celestial bodies in eternal circular orbits, how can terrestrial objects independently make contact with them? The only source Aristotle could invoke would be the natural tendency of certain elements, such as air and fire, to rise to the heavens. Of course, to have movement in that direction, those elements must not be in their natural place . Can the unmoved mover by responsible for that predicament by imparting eternal circular orbit to heavenly bodies? In *On Generation and Corruption* Aristotle tries to account for the changing dispersion of the different elements through the processes by which they change into another. [9] Once more, however, the setting into motion of those processes calls for explanation, which Aristotle supplies by referring to the inclination of the heavens, which allows the unchanged revolutions of celestial bodies to impact upon terrestrial substances in an irregular fashion. [10] That explanation, however, assumes without explanation that the elements are already estranged from their natural places.

Aristotle is in no position to buttress his account by invoking any law of action and reaction any more than by invoking inertia and gravity . The communication of action and reaction involves a general reciprocity among interacting bodies. In the discussion of justice in Book V of the *Nicomachean Ethics* Aristotle does discuss reciprocity in conduct . [11] Although he allows for a retributive justice that mandates an arithmetical equivalence between losses and gains of what individuals are due, this equalization rests upon the geometric proportionality of distributive justice, where individuals receive publically distributable goods in ratio to their merit. Here it is their specific ethical character that determines what they deserve. Universal reciprocity must give way to an acknowledgment of different acquired natures of individuals, according to which those whose conduct has made themselves better should receive more political power, wealth, and honor than those whose conduct has made them worse. Only when distribution has already been achieved on these terms where unequals receive unequal deserts, can retributive justice permissibly perform its rebalancings where wrongs are remedied by equivalent compensation.

Something similar goes on in Aristotelian physical nature to the extent that material substances undergo changes in function of their specific form. With early modern philosophy, substance becomes conceived such that form drops out of consideration. Substance now signifies little more than formless matter, the universal substrate of all natural determinations, which now figure as accidents, determined externally with indifference to what a body is. Nature thereby becomes a world of law as opposed to a realm of form. Accordingly, the difference between the heavens and earth falls away, as the same laws of matter apply everywhere to everything. Kant’s pure mechanics exemplifies this transformation. As we shall see, Hegel will distinguish three different types of motion that apply on the one hand to matter in general, but on the other hand to different types of bodies occupying distinct locations.

6.2 The Impoverishment of Natural Process by Kantian Pure Mechanics

Kant offers his last word concerning the restricted boundaries of the philosophical consideration of nature in the final Chap. 4 of the *Metaphysical Foundations of Natural Science*. Under the heading of the "Metaphysical Foundations of Phenomenology", Kant presents his fourth and final definition of matter: "Matter is the movable insofar as it, as such a thing, can be an object of experience." [12] How, then, is the motion of matter determined as an appearance for us? Not surprisingly, Kant answers this question by invoking the categories of modality (possibility, actuality, and necessity), which the *Critique of Pure Reason* employed to characterize how objects of experience generally stand in relation to our cognitive faculties. What distinguishes the discussion in the *Metaphysical Foundations of Natural Science* from the corresponding account in "the postulates of empirical thinking in general", which concludes the Principles of Pure Understanding, [13] is the application to the motion of material objects.

Proposition 1 of this chapter addresses how the motion of matter is determined in respect to possibility and impossibility. In the *Critique of Pure Reason*, the first postulate of empirical thinking in general ascribed the category of possibility to "whatever agrees with the formal conditions of experience (in accordance with intuition and concepts)". [14] Now, in Kant's examination of matter in motion, the category of possibility applies to the motion of a body whose opposite motion is equally possible. What kind of motion can this be and why? Kant offers rectilinear motion as paradigmatically possible, that is, as having an equally possible opposite motion, insofar as it proceeds "with respect to an empirical space". [15] Empirical space is always relative insofar as it involves bodies whose rectilinear motion can appear to be a movement of one towards the other just as well as a movement of that other to the first. Moreover, the motion of bodies with respect to one another can equally appear in relation to a backdrop of further bodies in motion. The first "inertial frame of motion" can then appear to be moving rectilinearly in one direction with regard to the other framework (viewed as being at rest), or equally appear to be stationary while the other "inertial frame of motion" moves rectilinearly in the opposite direction.

On these terms, we can never be sure that any appearance of rectilinear motion is actual because its opposite might equally be actual, depending on which object is regarded as stationary, as well as which inertial frame of reference is regarded as moving. Indeed, not only might any supposed rectilinear motion of a body be equivalent to its opposite, but it can be converted into an infinite number of intermediary motions depending upon what speeds are ascribed to other bodies and their backdrops. Kant's discussion of phoronomy already showed how the linear motion of a point exhibits this relativity, and now, with application to bodies in motion, the same relativity renders rectilinear motion of matter merely possible.

The appearance of bodily motion loses mere possibility and gains actuality, Kant maintains, when matter moves in a circle. As Proposition 2 affirms, "The circular motion of a matter, as distinct from the opposite motion of the space, is an actual predicate of this matter; by contrast, the opposite motion of a relative space , assumed instead of the motion of the body , is no actual motion of the latter, but, if taken to be such, is mere semblance." [16] In the second postulate of empirical thinking in general in the *Critique of Pure Reason*, actuality supplanted mere possibility when "agreement with the formal conditions of experience" was supplemented by

sensation, that is, a connection “with the material conditions of experience”. [17] Sensation, however, can be at hand in the experience of both rectilinear and circular motion of material bodies. Why should only circular motion provide matter with the actuality of movement? What is it about circular motion that, unlike rectilinear movement, removes any ambiguity about whether a body is actually moving in a determinate way? Does circular motion allow us to experience an absolute space as well, where change in location is no longer apparent but indisputable?

Kant acknowledges that from the point of view of appearances one can just as well imagine that what appears to be moving in a circle is actually stationary, whereas what appears at rest is actually whirling around the erstwhile circling body . Alternately, one can just as well imagine that a clockwise circling body is not moving at any particular velocity, but that everything else is rotating counter clockwise at various possible rates, each of which alters the actual velocity of the circling body . If these options are all equivalent, as far as appearances go, how can circular motion have some privileged actuality?

Aristotle gave circular motion primacy among all change, given its continuous constancy that allowed it immediately to issue from an unmoved mover. For Kant, all change in any objective sense is locomotion , and for this reason, he has no qualms about using “motion” and “locomotion ” interchangeably. Since objective changes are ultimately alterations in spatiotemporal position, the actuality of circular motion could be said to give it the privilege of being the only *actual* change in the universe, as we can experience it.

To support the ascription of actuality to circular, but not rectilinear motion of matter, Kant invokes the law of inertia . According to the law of inertia , a body engaged in circular motion would continue moving in a straight line unless some additional force is continually applied to it to keep it moving in a circle. On these terms, circular motion results from the movement of a material body being continuously impeded in infinitesimal degrees from going in a straight line, thanks to the external action of some constant force. Consequently, what insures the actuality of circular motion is the actual presence of the moving force of some other body or bodies. This removes the ambiguity of circular motion insofar as everything else cannot be rotating around the seemingly circling body if no moving force is present to cause their rotation. Since the alternate motion leaves the apparently circling body as the only material substance available to exert moving force on all the other bodies, their putative rotations evidently lack sufficient cause. Although from a phoronomic point of view, circular motion might seem just as relative as rectilinear motion, when moving bodies rather than points are at stake, the force needed to counter inertia removes the phoronomic equivalence. Whereas phoronomically, the circular motion of a body is no different from everything else moving in a counter clockwise direction from the same center point, mechanically speaking, very different moving forces must be invoked. When they appear, the ambiguity of circular motion is eliminated and the single body ’s circling movement commands actuality.

It is worth noting that to experience any motion of a material substance, more than one object must appear to us. Rectilinear movement requires at least one other body whose distance perceivably alters, whereas circular movement requires the observability of some determinate background against which rotation can appear, as well as the observability of some other object to exert the requisite moving force to counter inertia .

Something else is at hand in the experience of motion that Kant hardly mentions. Namely, the appearance of motion, be it rectilinear or circular, presupposes an observer in a determinate location, whose own position may be subject to movement, either possible or actual. Whether

one considers the appearing motion to be absolute or relative to other appearing material objects and inertial frames of reference, every experience of motion still seems relative to the spatiotemporal location of the observer.

Does this underlying perspectivity undercut Kant's ability to tie actuality to circular motion?

Kant maintains that in the complex of all possible material experience, only the circular motion of a body , rather than the counter rotation of everything else around the center of the former's rotation, can be actual. To support this claim, Kant refers to various experiments that have shown the actuality of the earth's rotation on its axis. That rotation is confirmed by observations of how a pendulum alters its motion at different latitudes, as well as by how, when a material object is dropped from a height to the earth's surface, the object does not go straight towards the center of the earth, but deviates from that direction owing to the effect of the turning of the earth on its axis. [18] These examples, however, do not just rely upon circular motion, but combine it with something else: the fall of an object to the center of gravity of a much larger rotating body . This produces a motion that is neither linear nor circular, but curvilinear.

Such examples point to the relation of circular and linear motion and to what extent the purported actuality of one and the purported possibility of the other interact, given inertia and gravity . Aristotle placed circular motion at the basis of all linear and curvilinear motion, albeit without allowing for inertia , gravity , or action and reaction. Does Kant's assignment of actuality to circular motion and mere possibility to linear motion, make circular motion ultimately generative of all other motion as well?

Complicating matters is Kant's Proposition 3, "In every motion of a body , whereby it is moving relative to another, an opposite and equal motion of the latter is *necessary*." [19] What does Kant mean with regard to motion of one body relative to another? Is it simply what we have in linear motion, where opposite motions are equally possible? Their equal possibility might be necessary, but this does not entail that the occurrence of one such motion necessitates the occurrence of its opposite. Admittedly, on purely phoronomic terms, the motion of one point towards another is equivalent to the motion of the latter towards the former. Is Kant affirming something more, something that would underlie the necessary action and reaction of interacting bodies?

Kant's third proposition only adds to the first proposition of possible motion if what is at stake is not the equivalence of relative motions but rather the mechanical interaction of moving bodies, where the motion of one necessarily entails the equal "reaction" of the other. Action and reaction, however, is ordinarily associated not with forces (such as gravity) operating at a distance, but with the collision of bodies, where the impact of one is reciprocated by the opposite moving force of the other. Kant's third proposition does not limit itself to mechanical interaction where bodies make contact, but rather refers to any relative motion, no matter how remote the objects may be. In the Proof to this proposition, Kant refers to how the Third Law of Mechanics (Proposition 4) rests "the communication of motion of bodies" upon "the community of their original moving forces". [20] If the community of original moving forces is to be extended to coexisting bodies in general and render their respective motions mutually necessitated, then universal gravitation would be the obvious candidate for providing the moving forces that would always apply to the relative motion of material bodies. In this way, action and reaction would be emancipated from restriction to actual collisions of bodies and be able to represent the material analogue to Kant's Third Analogy, which ties the objective coexistence of phenomena with their mutual influence. To the extent that coexistence applies to all objects in the universe at any moment in time , their community would depend upon the manifest influence that their presence

exerts upon one another no matter how distant they may be. Universal gravity , which the dynamic conception of matter renders inherent in material substance, provides the ground for Proposition 3's necessity of relative motion to the extent that the attractive force of bodies to one another is exerted in opposite directions and can be equated by taking into account their respective accelerations. What would allow their accelerations to be different, and not just equivalent phoronomic motions, would be the relations of the two bodies to the inertial frames of reference of other bodies. Of course, the calculations become endlessly complicated due to the gravitational attractions exerted by all coexisting bodies, including those in any "background". Nonetheless, the daunting difficulty of calculating the resulting motions of coexisting bodies does not mean that they are not determined by the community of their moving forces.

Kant, however, maintains in his proof for this third proposition that the necessity of equal and opposite motions "does not rest (as in the second Proposition) on the influence of external forces, but follows immediately and unavoidably from the concept of the relation of the *moved* in space to anything else *movable*". [21] That relation seems at first glance to abstract from any consideration of the equality of moving forces and reduce itself to a phoronomic calculation of points in relative motion . "The *moved* in space" and "anything else *movable*" are not just points, however, but material substances on which moving force can be exerted and which can wield moving force in turn. What allows the objects in question to move relative to one another with opposite and equal motion without "the influence of external motion" would be none other than the "original moving forces" inherent in their respective masses, namely gravitational attraction. That, of course, would enable their community to apply independently of any surface contact.

If Kant's account were not grounded on universal gravitation a problem arises that he does not explicitly address. Namely, given that each moving body is moving relative to not just one but an indefinite profusion of other bodies, how do we determine which of these objects is moving with "an opposite and equal motion"? To the extent that actual surface contact between two specific objects is not what is at stake, how can Kant identify just one other body as the object of reciprocated motion? If Kant had limited the proposition to the equal and opposite action and reaction of impacting material substances, the problem would not arise. Then we could experience the motion of one object relative to another under conditions where an amount of momentum will be communicated, involving both velocity and mass , entailing an identifiable equal and opposite motion (with equivalent momentum or moving force). If, however, the motions reflect action at a distance, the bounds of community and the communication of motion expand indefinitely. Moreover, insofar as the moving force is gravitational attraction, proportional to mass and inversely proportional to the square of distance, the community of influence will involve these terms in their multiple entanglements.

Whatever the case, if the determination of opposite and equal motion involves measuring the quantity of motion in a material way, then the mass of the objects must be established. How is that to be done? The only way would seem to involve observing how the bodies' respective motions impact upon the motion of a third body that both these bodies affect. That comparison will provide a ratio of their masses through the common standard of the third body 's motion. A scale provides just such a measure by registering the motions of a spring caused by the moving force of different masses. Although the relation of velocity and mass to force allows the moving force of objects to be equivalent with very different masses, the scale equalizes the velocity, as well as the inertial frame of reference, of the two bodies being compared and allows the difference in moving force to reflect the magnitudes of their masses.

Throughout Kant's discussion of the three propositions of the "Metaphysical Foundations of

Phenomenology", where motion is considered in regard to its possibility, actuality, and necessity, empty space seems to be presumed. Possible rectilinear motion appears to operate through empty space between bodies in relative motion . Actual circular motion appears to proceed at a distance from other moving bodies, rather than as a vortex amidst other vortices filling an uninterrupted plenum of matter. Finally, necessary equal and opposite motion of bodies in relative motion seems to involve bodies both being at a distance and moving apart. Nonetheless, towards the end of Kant's account, he insists that he wants to avoid invoking empty space. [22] Admittedly, empty space can no more constitute the existence of matter nor be an object of experience, at least without intervening between the filled space of material substances, which can affect our outer sense. Empty space is unobservable unless it falls outside of perceivable bodies or inside the interstices of porous substances.

Kant earlier pointed out that the dynamic concept of matter, whereby repulsive and attractive forces fill space, made it possible for bodies of the same volume to have different masses and different densities without recourse to empty space. [23] Instead of requiring different arrangements of atoms and voids to fill space to differing degrees, the dynamic conception of matter allows density to vary without an empty space within individual bodies. Can empty space, however, be dispensed with in accounting for the mechanical interaction of bodies and the working at a distance of gravitational forces?

The dynamic conception of matter may allow for different densities without empty interstices inside bodies, but that of itself does not preclude empty space between bodies. Kant, however, suggests that the dynamic conception of matter also mitigates against any empty space between material substances. Allegedly, any void would instantaneously collapse since empty space between bodies can offer no resistance to their mutual attraction. Moreover, since any void would require such attraction to be countered by a balancing repulsion, empty space would end up containing the same combination of attractive and repulsive forces that constitutes matter in the first place .

In denying empty space between bodies, Kant imagines that each body has no cohesion except through compression by external matter ("the aether"), which wields pressure in virtue of the universal and original attraction in which gravity consists. Supposedly, as the distance between large bodies increases, the attractive force they wield on their surrounding "aether" diminishes, making that ether expand to fill up all the intervening space. [24]

In employing the ether to exclude empty space between bodies, Kant presumes that the cohesion of bodies depends upon external compression. Kant is thereby ignoring the original attractive force on which the very constitution of matter depends. Without repulsion and attraction operating together, the former immediately disperses to infinity, just as the latter collapses into a point, leaving no matter to compress or be compressed. The very presence of the ether as an external matter capable of filling space and compressing other bodies depends upon it possessing attractive force just as much as must any material substance with a volume that can be compressed. Only on the basis of their respective combinations of repulsion and attraction can they occupy space and exert gravitational force upon one another as discrete material substances. The cohesion of a body is therefore dependent upon its own internal repulsion and attraction. It cannot require something else pressing in on it, as if the filling of space could be explained by repulsion alone. Kant's dynamic conception of matter begins in this vein by employing repulsion to explain the filling of space without immediately bringing in attraction. Attraction then gets brought in as if it wields a kind of compression, as if there could be anything material to compress without attraction already being at hand. This makes it seem that gravitation is a force

of attraction between pre-established bodies, whose boundaries are based upon the external pressure of competing forces of repulsion.

The incoherence of this explanation makes it apparent that the dynamic conception of matter cannot preclude empty space between bodies. Insofar as determinate volumes are filled through a combination of attraction and repulsion, neither of which can operate independently of the other, bodies can have discrete boundaries without having to press upon one another. Indeed, if empty space were precluded, how could the plenum of matter avoid compressing itself through gravitational attraction, leaving empty space where matter once stood?

Kant's account of mechanics exhausts itself at this juncture. The foundational epistemology pioneered by Kant leaves us with a pure mechanics whose three governing principles provide virtually all that can be known universally and necessarily about material nature , if the project of Kant's critical philosophy is followed. Kant leaves us with repulsion and attraction, a constant quantity of matter, inertia , universal gravitation, and action and reaction. He adds further corollaries, but these offer nothing fundamentally new.

Can reason tell us nothing more about nature ? Hegel will offer us a path beyond the limits of pure mechanics.

6.3 Hegel's Rethinking of the Mechanics of Matter in Motion

Hegel begins his account of matter in motion with what he identifies as finite mechanics, [25] which encompasses generally everything that Kant presents under the metaphysical foundations of mechanics. Hegel's discussion is based upon a rethinking of the dynamic constitution of matter , which presents a more consistent version of what Kant does in trying to conceive how matter consists in a force field involving coeval aspects of attraction and repulsion. This rethinking conceives how there can be an occupant of space that remains self-identical as it changes its place , uniquely excluding any other body from the volume it inhabits as it moves or lies at rest. Matter here consists in a unification of an internal self-repulsion and self-attraction, which fills space in a continuous manner, while bounding itself and thereby becoming a determinate body distinguished from any other potential body . With matter establishing itself as an exclusive body , differentiated from indefinitely possible other material entities, gravity comes into play as the very substance of the body as individual and individuated from others. Through matter's bounded, exclusive unity of self-repulsion and self-attraction, each body constitutes a gravitational field , both containing the body 's own extension and attracting all other bodies in proportion to their mass and in inverse relation to the square of their distance. Matter thereby forms an individual body , combining attraction and repulsion in occupation of an exclusive place with a center of gravity in which these coeval forces are focalized. [26] By this means, each body stands in relation to every other body through its respective center of gravity . Their relationship has this basic character, which in no way determines either how many bodies there are, what mass they have, or where they are located. The dynamic constitution of matter and gravity leaves undetermined the relative size of individual bodies and their position in space-time .

Nevertheless, as we shall see, both the workings of gravity and the physical processes that bodies acquire through the differentiation of matter will have definite consequences for the movements and distributions of matter in the universe. In the first place , as Hegel will duly show, the centers of gravity of different bodies together generate consolidated centers of gravity outside of them all, towards which they all are impelled to move. In this way, the dynamic constitution of bodies pushes them beyond themselves, just as their own constituent matter draws towards a central point to which it can never all arrive. In both respects, material entities strive to attain centers of gravity to which they can never arrive without cancelling their own extension and collapsing into an immaterial point. If bodies could reach this ideal destination, they would cease to have any dynamic constitution and forfeit any mass they might have. In this way, material bodies' own centers of gravity give matter an ideal character, to whose immaterial focal point matter intrinsically strives. [27] Whereas Aristotle tied a striving to a determinate place to the specific nature of different elements of material substance, Hegel recognizes that matter as such strives to centers of gravity engendered by matter's own dynamic constitution. As Hegel points out, centers of gravity are not material points, but rather ideal centralities to which matter gravitates, both within and without each body . [28] Even when a center of gravity lies inside a body , it is not a conglomeration of a determinate amount of matter, such as might be thought to be sucked up into a black hole, but a point from which the gravitational force of the body emanates.

Although Hegel acknowledges gravity to be the very substance of matter, setting matter in motion through its own dynamic character and contingent dispersion, [29] he still conceives bodies to be inherently subject to externally impelled motion, such as pure mechanics delineates. Bodies may be constituted with centers of gravity that make certain motions intrinsic to matter, but bodies are equally subject to having motion imparted to them and to imparting motion to other material objects. Matter is indeed moveable and contributes to moving itself once it has become an individual body with a center of gravity through which it attracts and is attracted to other bodies and their consolidated centers of gravity . At the same time , individual bodies may be moved and move other bodies through mechanical interactions that go beyond the motions of gravitational attraction. This is inevitable due to the moving force of gravity and the contingent, indeterminate number, size, and location of bodies. Matter as such will be moveable and involve motion that has an external character, completely indifferent to the specific nature of any individual body .

In other words, material bodies will have inertia , even though they have centers of gravity and wield the moving force of gravitational attraction. Inertia signifies, as Kant well recognized, that matter is subject to changes in motion from without as opposed to from within. A key basis of matter's inertia lies in how the dynamic constitution of matter as occupying a place that is moveable in no way determines bodies in their specific plurality nor where they are in respect to one another at any time . All the dynamic constitution of matter mandates is that bodies are excluded from simultaneously occupying the same place , not how many bodies there are nor how they are distributed. This makes bodies susceptible to suffering external impacts, as well as to externally impacting upon other bodies. Accordingly, Hegel follows the dynamic constitution of matter with the determination of inertia and thrust, which the indefinite dispersion of bodies with centers of gravity makes possible. [30]

Nonetheless, Hegel equally understands that matter's motion cannot just be inertial. Indeed, the only place where we can encounter inertia in and of itself is when objects move in a transversal trajectory maintaining an equal distance to their centers of gravity . Such is the case of much terrestrial rest and motion to the extent that it is located on the earth's surface, remaining in a relatively unchanged distance from the centers' of gravity that wield the greatest noticeable gravitational attraction. So long as objects lie at the same elevation from the earth's center, gravitational force from that center varies little, just as does that emanating from our sun and, to a lesser extent, from our moon . This applies equally to the interaction of bodies in the weightless conditions of uniformly orbiting space vehicles or at the apogee of suborbital ballistic flights. Within such specific parameters, defined by the relation of bodies of vastly different mass , inertial motion and mechanical communication of such motion can occur, largely unimpeded by gravity . Other earthly trajectories will instead subject the movement of bodies to combinations of inertial motion and fall , where objects accelerate towards a body of much greater mass . Such a combination is exhibited in projectile motion, where transversal inertial motion eventually is brought to a rest determined by the gravitational attraction of falling.

These distinct situations show how within specific limits, bodies will be subject to changes of motion imparted from without that are independent of both the specific nature of the object and gravitational forces.

On the other hand there are further forms of the motion of bodies where their movement is more and more determined by the character of matter itself, diminishing the extraneous relationship of motion to matter. Moreover, the different types of motion stand in a definite relationship to one another. Inertial motion, where matter is moved from without, is going to

operate within the interstices of a situation in which bodies are subject to fall towards a much larger body exerting overbearing gravitational attraction. This second type of motion, which Hegel identifies as “falling”, [31] is determined differently from inertial motion, even though it is possible, following Newton, to convert the laws of fall to derivatives of the communication of inertial motion. The communication of external motion through impact is a function of the product of the mass and velocity of the objects involved, and entails an invariable motion, with allowance for the elasticity of the respective bodies. By contrast, fall involves a constant acceleration where the speed increases in function of the duration of the fall (i.e. velocity is the product of gravity and elapsed time). Here, differences in the mass of the falling objects drop out of consideration, having no appreciable consequence. This is not due to the huge disparity between the mass of the earth and that of falling objects, with renders the earth (or any comparably larger body) the center to which they all descend. It rather directly follows from how the way in which the force of gravitational attraction is related to the mass of the bodies in question is balanced by how more force is required to accelerate a larger mass . Whereas, in Newtonian terms, the gravitational force equals the product of the mass of the attracting bodies and the gravitational constant, divided by the square of their distance ($F = GM^1 \times M^2/R^2$), and force equals mass times acceleration ($F = MA$), then, letting A be the acceleration of the falling body (M^2), it follows that $M^2A = GM^1 \times M^2/R^2$, leaving the acceleration of the fall $= GM^1/R^2$, where the mass of the falling object falls of out consideration.

Fall is different from inertial motion in that fall has an aspect that is contingent and another aspect that is inherent in the matter of the falling body . What is contingent is the position from which the falling object begins its descent. What is not contingent is the weightedness of the falling body , which is intrinsic to the body in virtue of its mass and the gravitational attraction to which it is necessarily subject in the situation of fall . Although a body as a body has weight unless gravitational and/or inertial forces evenly balance, Hegel notes that weight is a relative gravitation. [32] This relativity is exhibited by those planetarium displays that offer scales registering our weight as it would be on the surface of different planets. The weight of a body will vary, of course, depending upon the mass of whatever planetary body is the predominant center of gravity to which a body falls, unless intervening objects or other moving forces prevent further descent. Nonetheless, difference in weight will still not affect fall , since fall towards the same center of gravity will be determined by its duration, rather than by the weight of different falling objects.

Fall operates in the specific situation where one or more bodies are subject to the gravitational attraction of another body so comparatively massive that they all accelerate to that central body ’s center of gravity . Their acceleration is a constant fixed by the very nature of their being weighted. This constant is relative to the mass of the central body that is attracting them all so it might not be equivalent to the operating constant of fall on our lonely planet . It will, however, be a constant of some specificity reflecting the magnitude of the centrally attracting body . What is determined by neither the gravitational constant of fall nor the weight of any falling object is where bodies begin their fall .

Whatever the case may be, the context will be one in which inertial relations will have a subordinate role to play. Inertial relations will have most room to operate where bodies of relatively small scale interact with one another. Their mass will be small enough that gravitational attraction will have comparatively minor effect upon the communications of motion external to the bodies in question. Fall will supplant inertial conditions when there is a radical imbalance between the mass of some central body compared to those others caught in its

gravitational sway.

This circumstance occurs in the general environment where bodies are found on or near the surface of planetary bodies, which dwarf all their “terrestrial” occupants in scale. Only because of the vast difference in scale will the varying masses of terrestrial objects not have any appreciable affect upon their being subject to fall . Although gravitational attraction remains conditioned by the respective masses of the bodies involved, when one hugely exceeds the others, their masses wield virtually negligible gravitational forces on one another. Hence a feather and a cannon ball will fall with virtually equivalent acceleration , provided one subtracts the effects of air resistance.

Although fall and inertial motion are bound up with different types of situations, these circumstances are not directly tied to the specific nature of the bodies involved. All that comes into play is their relative mass and respective positions. As we shall see, however, when differentiations of matter come into play with the physical processes they entail, differences in mass end up bearing upon the nature of the bodies in question. Bodies of sufficient magnitude will constitute planetary, rather than terrestrial bodies, and this will give them distinctive geological features. Further, when planetary bodies attain enough mass to generate gravitational forces igniting atomic fusion, they will become stars. These will then be home to special physical processes that will exclude others, such as chemistry and life, which can only occur on planets or sizable moons.

Despite these ways in which distributions of matter affect the occurrence of different types of motion, fall and inertia are hardly mutually exclusive. Terrestrial movements can combine both fall and inertial effects, as in the migration of pendulum swings and ballistic motion. Further, fall that results in impact will involve a communication of motion, with action and reaction, even if the great disparity in mass of the colliding objects will leave planetary perturbations largely negligible. Moreover, falling objects can themselves collide, with more noticeable inertial consequences, just as planetary bodies of comparable scale can hit one another with catastrophic communications of motive force. Hence, although bodies cannot escape gravitational forces, their inertia is neither precluded nor in contradiction with the gravitational force inherent in individuated matter. Instead, neither fall nor inertia have mutually exclusive domains in which each has absolute sway. The distinction between celestial and terrestrial motion is not completely illusory, but it does not undermine the universal application of laws of gravity and laws of inertial motion.

The examples of ballistic motion and the swinging of a pendulum are illustrative of how fall and inertial motion become inextricably linked. Whenever a projectile is launched from a planetary surface, it has motion imparted to it, with the expected inertial effects. Since, however, the projectile has mass and is weighted, it is subject to fall . Instead of moving in an inertial straight line, the projectile will follow a curvilinear or parabolic path, combining fall and inertial movement.

Similarly, a pendulum may appear to swing without end, but this cannot occur owing to the effects of friction, which gradually slow the pendulum down. Inertial considerations might lead one to imagine that the motion imparted to the pendulum will continue without end, so long as no counterforce is applied to it. As Hegel points out, the countervailing effects of friction are inevitable, since the pendulum has a mass and weight, putting pressure on its axle with every fall to the bottom of its swing. [33] As a material body , the pendulum occupies space in a way resistant against the other parts of the mechanism and weighs upon them, as a terrestrial object subject to fall . That fall acts against the transversal motion of the pendulum, generating friction and heat .

These consequences are not extrinsic, but endemic to the material reality of the pendulum. The material body as such is liable to externally imparted motions independent of its own gravitational interactions, to which it is inescapably subject. The comparative magnitudes of each type of moving force will depend upon the relative size and position of the bodies in question, which is contingent. What is not contingent is the interplay of gravity and inertia .

In conditions of fall , gravity can be said, as Hegel observes, to wield attractive, but not any repulsive force. [34] The gravitational force of the planetary body acts upon its terrestrial objects only so as to draw them to its overwhelming center of gravity . The resulting motion of fall exhibits attraction, but does not repel any bodies from one another. For just this reason, the distance at which fall begins is completely external to fall itself.

Motion takes on a different character when inertia and fall are superseded by what Hegel identifies as the encompassing motion of absolute mechanics. In absolute mechanics, the conditioned aspects of both inertia and fall are overcome. Unlike inertial motion, bodies in absolute mechanics move without having motion imparted externally to them. Unlike fall , bodies in absolute mechanics are attracted, but equally move away from their centers of gravity , forging paths whose arrival and departure are no longer contingently given. Here the material character of bodies entails both the attracting and the repelling dimensions of their movements. In other words, the formerly extraneous aspect of where objects start their fall is no longer unaccounted for; rather, bodies here move in a manner that is inherent to them, that is, in accord with their concept. Hegel here can invoke the concept, [35] not simply because conceptual determination specifies what pertains necessarily and unconditionally to entities. Rather, here we are dealing with what pertains to the concept of matter and how it is determinative of the various dimension of motion.

Absolute mechanics comprises a gravitational system determining all aspects of the motions of the bodies it involves. It constitutes an independent, self-sustaining system of motion. Absolute mechanics involved a system of matter in motion that does not and need not depend upon an unmoved mover. Nor does the system of absolute mechanics depend upon anything else extrinsic to the bodies it contains. Instead, absolute mechanics is the self-perpetuating complex of motion in which bodies as bodies have a center of gravity and thereby relate to one another in terms of a center of gravity lying outside them. They move in virtue of that relationship to one another, and, as such, they have their motions thoroughly determined. Absolute mechanics thereby forms a self-moving system of motion. Since inertial externalities and the contingencies of fall must be largely avoided, the participating bodies must transcend terrestrial limitations and operate on a celestial scale.

Hegel acknowledges that the stars have an array that is full of contingency . [36] Their dispersion in the universe does not appear to exemplify absolute mechanism insofar as their character as bodies does not determine where they are with respect to one another. Their positions instead appear contingently given, at least as long as we cannot integrate them in larger systems of intra- and inter-galactic motion. When, however, we consider a solar system , such as our own, we find a system of bodies in motion whose character as material entities with centers of gravity is fully determinative of their movement. It is fully determinative insofar as there is no need to appeal to anything outside the system to understand how its components move. The gravitational attraction of its participating bodies accounts for the motions they follow. In this respect, they together form a system of motion, determined in and through itself. The bodies still stand in purely mechanical relationship to one another since the changes they undergo in absolute mechanics are restricted to locomotion . Whatever further physical alterations intercede

owing to the electromagnetic character of the sun and the other orbiting bodies depend upon other natural processes that presuppose and incorporate those of the pure mechanics of undifferentiated matter in motion.

Nonetheless, the absolute mechanics of a solar system does involve distinctions in purely mechanical relationships that depend upon material differences that are not indifferent to the physical relationships that accompany the ensuing motions. Hegel takes these into account, identifying different types of bodies with respect to the role they play in this system of motion. [37] These roles are interrelated, for certain bodies cannot perform their particular role without other bodies engaging in the distinct roles they play. These roles are distinguished in terms of purely abstract material features of mass and motion. To begin with, the system contains a central body around which the others orbit. Secondly, among those orbiting bodies, some will equally play the role of a central body to satellites of their own that orbit them as they orbit the central body . Others, by contrast, will orbit the central body without having any satellites of their own. In other words, the solar system will contain a sun around which planets will orbit, some of which having moons of their own that orbit them.

One could extend absolute mechanics beyond the confines of a solar system to entire galaxies, where isolated stars, as well as solar systems, orbit a central conglomeration of matter, such as a black hole. Then one could, following Kant, go beyond a galaxy to a universe of galaxies orbiting around an ultimate cosmic center. In each case, absolute mechanics would operate so long as the motions are determined by the gravitational forces inherent in the bodies involved, rather than by any extraneous source.

Whatever its ultimate reach, absolute mechanics comprises an independent system of matter in motion, determined by nothing other than its component bodies' character as material entities having a center of gravity through which they are drawn around a further center of gravity that is itself determined by their own combined motions. Unlike Aristotle 's eternal circular motion of celestial bodies, which depends upon their love for an immaterial unmoved mover, absolute mechanics stands on its own, relying on nothing more than the dynamic constitution of matter out of space-time .

Absolute mechanics, however, is not exhaustively determining of all that proceeds within its cosmic process. Although its system of self-sustaining motion determines the spatio-temporal location of its member bodies with regard to their respective masses, it does so while encompassing occurrences of the other two forms of motion. On the one hand, absolute mechanics operates alongside the terrestrial fall of bodies, whose descents occur within the inertial frames of orbiting planets and their satellites. On the other hand, absolute mechanics proceeds while inertial motion takes place on terrestrial habitats as well as when celestial bodies collide, communicating motion and precipitating action and reaction. Significantly, inertial motion and the mechanics of fall provide all that is necessary for bodies to become integrated within the self-sustaining motion of absolute mechanics, whether on a solar system , galactic, or inter-galactic scale. Within these systems of absolute mechanics, the forms of finite mechanics take on their ultimate reality as elements of these encompassing astronomic totalities.

Whereas Kant regards his pure mechanics as bringing closure to reason's attempts to know nature a priori, Hegel recognizes absolute mechanics to bring closure only to the conception and reality of the motion of matter as such, which thereby sets the stage for the thinking and realization of the physical processes wherein matter becomes differentiated. Hegel does so by focusing on the solar system as a self-contained complex of matter in motion. Because the solar system mechanism accounts for all aspects of the movement of its components, it is not a relative

mechanics, in the way in which inertial motion is relative to external movers and fall is relative to the initial position of falling bodies. The self-sustaining movement of the solar system is an absolute mechanics, resting on itself, but pertaining to nothing other than the motion and mass of the bodies it contains. For this reason, Hegel can point out that here nature constitutes a system in which the entire form of its movement is determined by the character of matter as such. Herein matter is subject to quantitative determination, both with regard to its mass and motion, for, as of yet, no qualitative differentiation of matter has been mandated by nor entered into the system as it functions. Admittedly, the solar system distinguishes types of bodies in regard to their orbital roles and their respective masses. Nonetheless, the differentiation of central body , planet , and satellite does not yet carry with it the qualitative physical processes that turn out to underlie the formation of solar systems around stellar nuclear furnaces from which different types of matter are generated.

Hegel develops the absolute mechanics of the solar system in terms of Kepler's three laws of planetary motion. Are these laws themselves philosophically mandated? Are they built into the character of matter in the way in which the law of gravitational attraction may be entailed, as Kant and Hegel both suggest, by the dynamic constitution of matter? Hegel himself admits that Kepler substantiates his laws by showing how his mathematical formula fit the data he has observed. [38] Kepler finds that planetary motion takes the form of an ellipse, whose outline maintains a constant aggregate distance from two foci, one of which represents the position of the sun , whereas the other has no material counterpart. As Hegel notes, Kepler knew that the orbits of the planets closely fit an ellipse with one deviation, which Newton tried to explain. [39] Namely, the planetary orbits deviate from a pure elliptical trajectory when they come closer to one another in their respective circuits. This deviation can be explained by taking into account how their changing gravitational attraction to one another affects their orbits around the sun , distorting the elliptical shape of their paths. By itself, the ellipse of planetary motion is determined solely through the relation of the planet and its sun . Newton attempts to derive this ellipse from two things: the gravitational attraction that pulls the planet towards the sun , and another force that allegedly pushes the planet away from the sun on a tangent. One can think of these competing factors as centripetal and centrifugal forces. Following Kepler's laws, the velocity of the planet does not remain constant as it goes around on its elliptical orbit. Nor does it retain a constant acceleration . Rather, the planet will periodically accelerate and deaccelerate, going fastest when it is closer to the sun and going slowest when it is farthest away. Newton will explain this variation in terms of how the centripetal and centrifugal forces change in function of gravitational attraction and the force that must counter it to keep the planet in orbit. As Hegel points out, Newton can give no explanation for why the force that counters the changing solar gravitational attraction should itself vary. [40] Newton therefore cannot show why planetary must take the form of an ellipse, given how Newton must invoke a varying centrifugal force, a tangential inertial force that the planet has in virtue of its speed and mass .

Kepler's laws, by contrast, determine planetary motion without having to refer to these dual forces at all. His first law of planetary motion determines planetary orbits to have the form of an ellipse. His second law accounts for the change in planetary velocity by maintaining that in equal times the planet will pass through sectors of its ellipse with equal areas. [41] This will allow the planet to accelerate when nearest the sun , since then the sector of its ellipse will diminish.

Kepler comes up with an additional law that compares the motions of planets orbiting in different elliptical paths. This law dictates that there will be a constant relationship between the cube of every planet 's average distance from the sun and the square of the time that it takes to

orbit. [42] Once more planetary motion is determined in respect to space and time , without bringing in the mass of the planets or the mass of the sun around which they are orbiting.

Hegel links the character of Kepler's laws of planetary motion to absolute mechanics' independent self-moving system of motion. Unlike Newton, Kepler does not have to appeal to changes in centrifugal forces for which no explanation is given. Planetary motion is simply determined in and through functions of spatial and temporal relations that directly apply to solar system movement. Although the distinctions of central body , planet , and satellite depend upon comparative orders of mass , planetary motion itself proceeds without further reference to the magnitude of these bodies.

This might seem to render the laws of planetary motion phoronomic rules, insofar as they seem to abstract from the material reality of the bodies they govern. Each law, however, is mechanical, rather than "phoronomic", because it applies to moving bodies insofar as they exert and are subject to gravitational forces within a context where differences in mass underlie the distinct interaction of a sun , its planets, and their satellites in the independent system of motion.

Whereas Aristotle privileges circular motion as primary among motion, Hegel suggests that elliptical, rather than circular motion has the distinction of being free motion, motion that no longer rests on the external conditions on which other forms of motion depend. [43] Whereas linear and circular motions both depend upon something beyond the matter of the bodies involved, elliptical motion is specific to a moving system whose material objects continue in their movement due to nothing but their own intrinsic character as bodies. Hegel acknowledges that only circular motion can be purely uniform. One can imagine something moving in a circle with varying speed, accelerating and decelerating, but this could not happen freely, but only in virtue of the moving force of other bodies. [44] Elliptical motion ties space and time together in a diversified, qualitative relationship, without depending upon extraneous factors, such as the external moving in inertial mechanics or the contingent starting point from which fall begins. Not only is elliptical motion of variable velocity, but it operates in respect to bodies that play qualitatively different roles in the solar system to which they belong. Inertial motion makes no such qualitative distinctions, whereas fall leaves all falling objects in a quantitative commensurability, while sharing a center of gravity .

We can look at absolute mechanics in connection with the specific laws given by Kepler or think more generally about what must be true of the gravitational system as an independent totality. Whereas it does not need anything beyond itself to be determinative of all the motions it involves, the bodies it encompasses move as nothing other than bodies in general. All sides of their motion are accounted for, not just their tendency to move towards a center of gravity , but also to move around it in a determinate way.

Significantly, the realization of the laws of Kepler is itself disturbed by perturbations that are endemic to absolute mechanics insofar as not just one planet , but multiple planets and their satellites orbit a star . In recognizing this, Hegel also observes that these laws leave undetermined whether and at what velocity solar system bodies are rotating on their own axes. [45] The Kepler laws also leave open what direction axial rotation takes and whether it occurs at an inclination producing the kind of procession characterizing the Earth's rotation on its axis. [46] Where then do these further determinations come from? Is there any need to go beyond relative and absolute mechanics to supply an explanation?

To the extent that gravity is inherent in matter, arising from the attraction and repulsion constitutive of material bodies, solar system bodies will predominantly be spherical, attracting their own mass to a center of gravity within, as well as to centers of gravity without. Moreover,

they will be subject to rotation as well as elliptical orbiting, given how inertial interaction as well as fall can intercede within the workings of absolute mechanics. Through these developments, matter proves itself to be self-moving, at least as a component of the celestial gravitational systems of absolute mechanics. It also proves itself to be subject to inertial externalities as well as to fall , provided the situation of material bodies allows for such interactions.

What absolute mechanism provides is the ultimate framework of matter in motion within which all further natural processes proceed. Is there anything pertaining to the motion of as yet undifferentiated matter, that is, of material entities as bodies pure and simple, that is extraneous to absolute mechanism ?

What about the theory of the Big Bang, or of competing, less popular notions, of periodic contraction and expansion of the universe? Do they address something that absolute mechanics takes for granted? The Big Bang might be said to account for the gravitational system that absolute mechanics takes for granted. Namely, the Big Bang provides an originating explosive constitution and dispersion of matter, through whose gravitational attraction swirls of gases form, which then eventually coagulate into stars and planets and their satellites, all expanding from their alleged point of origin . The Big Bang account, however, does not just involve space-time and matter and motion. It offers a cosmic evolution, a modern cosmogony that goes beyond the confines of absolute mechanics. Instead of operating with the undifferentiated force field of matter in general, the Big Bang operates with a profusion of differentiated atomic particles and electromagnetic processes, which are already at hand in the formation of the most rudimentary element, hydrogen. Only with these physical differentiations can gravitational pressure produce something that is no longer a mere mechanical movement, namely the specifically physical process fusing hydrogen atoms together. With such fusion and its generation of energy , we are dealing with electromagnetism , where particles have different charges and electromagnetic fields supervene upon gravity to enable stars to emerge and produce different elements, from which planets can arise and begin hosting chemical, rather than merely physical processes. Some of these planets may be gaseous, but others may contain solid rock and metal cores, on which an environment can arise that becomes a biosphere , in which, at some brief interlude in geological history, intelligent beings somewhere emerge who conceive what nature is. All of this brings into play more than mere space-time and the dynamic constitution of matter , which suffices for relative and absolute mechanics.

Although Kant, by restricting reason to pure mechanics , must regard all these further natural developments as contingent matters beyond philosophical apprehension, we need not, at least if we follow Hegel’s lead in regarding the differentiation of matter as a necessary feature of nature , on which our own engagement in philosophy depends.

Notes

1. Aristotle , *Physics*, Book VIII, Chap. 10, 266a10–11, in *The Complete Works of Aristotle* , I, p. 444.

2. Aristotle , *Physics*, Book VIII, Chap. 6, 259b32–260a11, in *The Complete Works of Aristotle* , I, p. 434.

3. Aristotle , *Physics*, Book VIII, Chap. 7, 260a27–260b14, in *The Complete Works of Aristotle* , I, p. 435.

4. Aristotle , *Physics*, Book VIII, Chap. 8, 264b20–29, in *The Complete Works of Aristotle* , I, p. 442.

5. Aristotle , *Physics*, Book VIII, Chap. 6, 259a14–19, in *The Complete Works of Aristotle* , I, p. 433.

6. Aristotle , *Physics*, Book VIII, Chap. 4, 254b14-32, Chap. 5, 257b13–15, Ch.6, 259b6–14, in *The Complete Works of Aristotle* , I, pp. 425, 430, 433–434.

7. Aristotle , *Physics*, Book VIII, Chap. 10, 266b28–267a12, in *The Complete Works of Aristotle* , I, p. 445.

8. Aristotle , *Physics*, Book IV, Chap. 8, 215a16–18, in *The Complete Works of Aristotle* — Volume I, p. 365.

9. Aristotle , *On Generation and Corruption*, Book II, Chap. 10, 337a9–15, in *The Complete Works of Aristotle* , I, p. 552.

10. Aristotle , *On Generation and Corruption*, Book II, Chap. 10, 336a33–336b16, in *The Complete Works of Aristotle* , I, p. 551.

11. Aristotle , *Nicomachean Ethics*, Book V, Chap. 3-5, 1131a10–1134a16, in *The Complete Works of Aristotle* , II, pp. 1785–1789.

12. Kant, *Metaphysical Foundations of Natural Science*, 554, p. 93.

13. Kant, *Critique of Pure Reason*, A218–226/B265-274, pp. 321–326.

14. Kant, *Critique of Pure Reason*, A218/B265, p. 321.

15. Kant, *Metaphysical Foundations of Natural Science*, 555, p. 94.

16. Kant, *Metaphysical Foundations of Natural Science*, 557, p. 96.

17. Kant, *Critique of Pure Reason*, A218/B266, p. 321.

18. Kant, *Metaphysical Foundations of Natural Science*, 561, pp. 100–101.

19. Kant, *Metaphysical Foundations of Natural Science*, 558, p. 97.

20. Kant, *Metaphysical Foundations of Natural Science*, 558, p. 97.

21. Kant, *Metaphysical Foundations of Natural Science*, 558, p. 97.
22. Kant, *Metaphysical Foundations of Natural Science*, 563, p. 102.
23. Kant, *Metaphysical Foundations of Natural Science*, 523, p. 62.
24. Kant, *Metaphysical Foundations of Natural Science*, 564, p. 103.
25. Hegel, *Philosophy of Nature* , §262–268, pp. 44–62.
26. Hegel, *Philosophy of Nature* , §262, p. 44.
27. Hegel, *Philosophy of Nature* , §262, p. 44.
28. Hegel, *Philosophy of Nature* , Remark to §262, p. 46.
29. Hegel, *Philosophy of Nature* , Remark to §262, p. 45.
30. Hegel, *Philosophy of Nature* , §263-266, pp. 47–56.
31. Hegel, *Philosophy of Nature* , Remark to §267–268, pp. 56–62.
32. Hegel, *Philosophy of Nature* , Remark to §265, p. 49.
33. Hegel, *Philosophy of Nature* , Remark to §266, p. 53.
34. Hegel, *Philosophy of Nature* , Zusatz to §268, p. 61.
35. Hegel, *Philosophy of Nature* , §268, p. 61.
36. Hegel, *Philosophy of Nature* , Zusatz to §268, p. 62.
37. Hegel, *Philosophy of Nature* , §270, p. 65.
38. Hegel, *Philosophy of Nature* , Remark to §270, p. 66.
39. Hegel, *Philosophy of Nature* , Remark to §270, p. 68.
40. Hegel, *Philosophy of Nature* , Remark to §270, p. 69.
41. Hegel, *Philosophy of Nature* , Remark to §270, p. 71.

42. Hegel, *Philosophy of Nature* , Remark to §270, p. 71.

43. Hegel, *Philosophy of Nature* , Remark to §270, p. 70.

44. Hegel, *Philosophy of Nature* , Remark to §270, p. 70.

45. Hegel, *Philosophy of Nature* , Zusatz to §270, pp. 81–82.

46. Hegel, *Philosophy of Nature* , Zusatz to §270, pp. 81–82.

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7. Physical Process and Light

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The mechanics of matter in motion provide nature , in both thought and reality, with the primary, elementary scaffold on which all further natural processes proceed. Although Kant may restrict reason's grasp of nature to mechanics, we need not abandon our exploration at this point and retreat to the philosophy of science, where philosophy resigns itself to reflect on the consistency of empirical scientific theories, to which all further knowledge of nature is relinquished. Instead, we can follow the lead of both Aristotle and Hegel in considering to what extent reason can conceive the physical processes by which matter becomes differentiated, leading not only to chemistry, but to the eventual emergence of life.

In distinction from mechanics, physical process constitutes a domain intermediate between the mechanism of matter in motion and the internal teleology of life. Although physical process depends upon the dynamic constitution of matter and the finite and absolute mechanics of bodies in motion, physics involves natural developments that are irreducible to what gravitational systems themselves determine. These natural developments will provide the enabling conditions for life, which will be just as irreducible to physical process as physical process is to mechanics.

In moving into physics from mechanics we enter a territory that Hegel, unlike Kant, considers just as philosophically accessible as the motion of undifferentiated matter. Physical process is a very crucial dimension of nature , without which there can be no understanding of how living beings could possibly inhabit and conceive the universe.

As before, we must proceed in accord with the systematic proviso that no aspect of nature can be and be conceived without the presence and account of those natural features that are its enabling condition. To avoid dogmatism, the philosophy of nature must first determine the most elementary, most minimal factors of nature that all further natural realities incorporate and depend upon. Space, time , matter, and mechanics successively provide the prerequisites for physical process. The domain of physics must now be determined with those resources at hand and in the order of constitution by which physical process itself unfolds. This does not mean that what follows is determined by the more elementary sphere, such that all further dimensions of nature are going to consist of nothing more than mechanism , nothing more than matter and motion. Everything else may indeed involve matter and motion, but as much as mechanics may provide the enabling conditions for everything else in nature , this does not mean that they provide the determining principles constitutive of physical process or life. The principles of mechanism may determine material conditions incorporated in all further aspects of nature , but they do not operate as first principles determinative of what comes to be on their basis. They are

rather going to be constituents that will serve as elements for processes that involve more than mechanics.

Besides following out how nature is constituted through the incorporation of enabling conditions at each level of natural development, we can guide our conception of the universe in light of another consideration. This is the recognition that any true conception of nature must present no ultimate obstacles to there being a science of nature . The true theory of nature must conceive the universe so as to allow intelligible life to arise and understand what the cosmos is in truth. It is questionable, to say the least, whether Kant's restriction of philosophical knowledge of nature to mechanics can satisfy this last proviso.

We now stand ready to draw upon Hegel to take us beyond the elementary process of mechanics to the physical differentiations of nature . In the *Metaphysical Foundations of Natural Science*, Kant left us with little more than an account of the first sphere of finite mechanics, containing what Hegel addresses under the heading of inert matter and thrust. We must turn to Hegel's account of finite mechanics to encounter a consideration of falling, and then to his account of absolute mechanics to arrive at a self-sustaining gravitational system of moving bodies.

Kant's own project of transcendental philosophy, that is, of foundational epistemology , drives him to terminate his investigation of nature at this juncture of finite mechanics. As we have seen, because foundational epistemology conceives all possible objects to be determined by the structure of cognition, nature is rendered a law-governed domain of material substances subject to the common external necessitation of efficient causality. What can be known universally and necessarily about nature is its lawful motion as a domain of pure mechanics , for this concerns those changes that are externally necessitated with indifference to what each object may be. Kant, of course, does not deny that objects of experience appear to have other features, but these are subject to nothing but empirical description, in which no strict necessities are fathomable. Since, however, all such empirically given qualitative features are mere accidents, it is questionable whether anything alive can be experienced as such, if what is living has specific features that are inherent to its life process.

Kant, like his early modern predecessors who distinguish primary from secondary properties, must consider that, unlike the rule-governed motions of bodies, all the qualitative features of natural entities that are given to the senses have a suspect objectivity. Kant must treat all these physical features to be subjective affectations, for his own account has no resources to lend objectivity to anything beyond what pertains to material causality and its regulation of matter in motion. He must follow this path, even though, as Berkeley had pointed out to no avail, there is no way of experiencing the motion of bodies without making use of secondary properties.

In joining Hegel to advance from mechanics to physical process, we enter a sphere of nature that falls between that of matter in motion and that of life. The domain of physics, as Hegel thinks it through, incorporates the finite mechanism of bodies in inertial movement and falling, as well as the independent gravitational system of absolute mechanics, but does not itself involve the processes specific to life. The itinerary consisting in the development of physical process is thus bounded by these two sides of nature . Physical process will begin on the basis of the free standing, self-operating gravitational system, which builds a universe of bodies. This material enabling condition involves both what could be said to be celestial and terrestrial dimensions, involving different kinds of motions reflecting how bodies have centers of gravity both within and without themselves, as well as differences in scale and relative position.

From this starting point, we will be conceiving what nature adds to that elementary

framework until it arrives at the threshold of life, transforming the physical world into a biosphere . Our task will be thinking through what constitutes inorganic nature and thereby provides the physical foundation for a nature that includes life and ultimately a form of intelligent life that can truly know itself and the universe it inhabits.

Broadly speaking, the domain of physical process comprises an inorganic nature , where bodies are no longer operating simply as undifferentiated masses, whose matter is not qualified in any further respect than how it moves within the gravitational system. The mechanism of matter in motion offers bodies that are distinguished by their spatiotemporal position and how they move with respect to one another. Although all of them are subject to the general principles of inertial motion, some will be subject to falling towards a significantly larger body , whereas larger bodies will be differentiated in terms of which figure as central bodies of gravitational systems, around which orbit other bodies, some of which have satellites of their own. So far, these differentiations do not distinguish the bodies involved with respect to anything other than their mass , motion, and center of gravity , which is all that yet pertains to whether they figure as terrestrial or celestial bodies. Among celestial bodies, some are central bodies, like the sun of a solar system , around which other bodies orbit in elliptical paths. Others are the planets that so orbit, while others are satellites of planets, moving elliptically around them. These satellites will rotate around their axes in relation to the sun , due to their path around their governing planet and will not have satellites of their own. Although planets may rotate around their own axes, this rotation is unrelated to their orbit around their sun . Hegel also distinguishes comets, which do not fall between the relatively concentric paths of planets, but drift through their orbits in a more irregular fashion. These four types of celestial objects comprise four basic ways in which bodies can be differentiated in terms of the gravitational system of absolute mechanics. In each case, however, they remain nothing but weighted bodies, with gravitational centers. They are not qualitatively distinguished in any further way. Rather, the gravitational system gives them various functions with different types of motion.

This sets the stage, Hegel tells us, for a further natural reality in which material things are going to be qualitatively differentiated in terms of specific features that reside in their own character. No longer can nature be adequately captured by simply focusing about matter and motion. We are now going to be speaking about matter that has an individuality , distinguishing it from that of other bodies. Here we are dealing with the qualitative determination of nature . We are not just dealing with matter that is governed by laws of efficient causality that simply specify bodily motion. Now we are talking about matter and material bodies that have a specific form. It is determinative of what they are and individuates them from other types of material entities. This qualitative differentiation involves more than merely motion. Mechanism is still going to be operative. Qualitatively distinguished natural entities do not cease being bodies subject to gravitational attraction, as well as inertial motion and fall . Now, however, they are going to take on a further character that will qualitatively distinguish them alongside the laws of matter that will continue to govern them all. Bodies will now possess an individuality above and beyond their mass and motion.

7.1 Preliminary Outline of the Divisions of Physical Process

Hegel offers us a formal preview of how the whole domain of physical process is to unfold in paragraph 273 of his *Philosophy of Nature* . In so doing, he takes us from the mechanics of matter in motion, where gravity rules, through the qualitative developments that allow the universe to become a biosphere , in which life can be actual. In spare terms, Hegel presents an order of constitution, where each successive stage incorporates what precedes it. He distinguishes first, “Universal Individuality ”, then, “Particular Individuality ”, and finally, the “total, free Individuality ”. [1] What comes under the first heading are the most minimal, elementary qualitative individuations of material things and processes, which incorporate what pertains to matter as matter, but none of the further physical specifications that follow. The “universal individuality ” of physical process involves the immediate qualities that are free from any reduction to gravitational determination. As elementary physical features, they are not mediated by any further physical process, but provide qualitative distinctions that enter into all subsequent developments in nature . By contrast, the “particular individuality ” of physical process involves the relation of such elementary physical form to gravity and how this form further determines gravity . Finally, the “total, free Individuality ” of physical process will incorporate the universal and particular individualities into a distinctly physical totality of nature .

What these three stages encompass remains to be seen. The first stage of universal individuality itself involves three successive sections. The first of these is characterized under the heading of “the free physical bodies”. [2] Here Hegel is addressing three types of physically differentiated factors, on which all further physical process depends.

Light comes first. Hegel presents it initially in conjunction with a particular kind of body , namely, the sun , or more generally, stars. Hegel next turns to what he calls “bodies of opposition,” identifying these with moons and comets. Finally, he offers as the third type of free physical body , planets as bodies of individuality . Although we are supposedly dealing here with a new kind of natural process, going beyond mechanics, the three successive bodies Hegel presents are clearly grafted upon a differentiation that has already been delivered in the free mechanism of absolute mechanics.

What then is fundamentally new in this allegedly physical differentiation of “three free physical bodies”? Has Hegel mistakenly tied supposedly physical types upon bodies distinguished by their role within a self-sustaining gravitational system? Within absolute mechanics, the bodies in question are characterized simply by how they interrelate in terms of gravitational attraction and motion. They are not here differentiated in terms of the putative physical processes that make the center of a solar system a light emitting star and the planets bodies of a different composition. Admittedly, Hegel has nothing to build upon other than what absolute mechanics offers, but are the most elementary physical differentiations to be mapped onto the three types of bodies whose different motions and relative masses comprise a solar system ? To evaluate Hegel’s proposal, we need to see whether the factors of this first subdivision of physical “universal individuality ” are the enabling conditions of what follows, as well as whether the order in which they are offered has any warrant of its own. In the meantime, it is worth noting that these three types of bodies exist as separately moving entities, rather than

as components of any other natural substance.

Following the “free physical bodies”, Hegel conceives what he categorizes as the “universal physical elements ”. [3] These are not the elements that are differentiated by atomic structure in the Periodic Table and underlie chemistry. Rather they comprise basic forms of matter that appear to match what Aristotle develops under the same heading, namely earth, water, air, and fire. As we shall see, what Hegel here differentiates are more akin to states of matter , such as solid (AKA earth), liquid (AKA water), gas (AKA air), and plasma (AKA fire). To the extent that these states are not unique to any “chemical” element, they can be and be conceived without taking into account the specific atomic structural differences that distinguish the elements of the Periodic Table . Can, however, the three types of “free physical bodies” be and be conceived without invoking the states of matter represented by the elements Hegel here introduces? Alternately, do these different states of matter themselves presuppose the different types of physical bodies, such that plasma is to be found on or emanating from a light emitting star , and gas , liquid , and solid forms of matter are to be found on the “dark”, merely “reflecting” abodes of planets, satellites, and comets?

Hegel follows the determination of the elements with the “process of the elements”, which Hegel describes as a meteorological process, constituting “the physical life of the Earth”. [4] Generally, the process of the elements is the physical process whereby states of matter get transformed into one another. Although the meteorological process of the earth, or of any other planet containing matter in different states, may exhibit these transformations, are these transformations necessarily situated on planets or additionally on certain satellites and comets? Hegel’s ascription of a “meteorological” nature to these transformations seems to tie them to specific types of “free physical bodies”. Admittedly, stars may contain matter only in the form of plasma and lack transformations of states of matter into one another. Even if stars may be thermonuclear furnaces producing “elements” of different atomic structure, they lack the “weather” that geologically “active” planets, comets, and some satellites may experience. Nonetheless, is Hegel bringing into his account of the process of elements extraneous features? Weather, after all, may involve not only phase changes of matter, but also chemical processes affecting temperature and humidity, some of which are produced by living organisms, including rational animals who alter their biosphere . The process of the elements should here consist simply in what pertains to the transformations of states of matter into one another. Whether these transformations are necessarily situated on certain types of celestial bodies is a question that Hegel’s account must answer. How these transformations may be impacted upon by specific geological formations and the presence of living things are matters dependent upon very concrete natural developments that cannot be at issue when physical process per se is at issue.

The transformations of forms of matter into one another are inherently mediated by astronomical conditions if “meteorology” cannot take place on light-emitting central bodies, but only on “dark”, “reflective” bodies (planets, comets, or satellites). Then it makes sense to follow Hegel and consider the individual phases of material transformation as astrophysical, and not just physical without further qualification. Putting the forms of matter into an astrophysical context depends, however, upon some prior account of how the different types of bodies in celestial gravitational systems themselves taken on distinct physical characters that pertain to what forms of matter they can host. That account is precisely what should be delivered in the first section of Hegel’s treatment of the “universal individuality ” of physical nature , where types of physical bodies are conceived, in connection, notably, with light, or more generally, with electromagnetism .

This first section should provide the qualitative distinction of physical bodies on the basis of which it becomes possible in both reality and thought to have the physical process where the qualitative “elements” of physical nature become transformed into one another in the so-called meteorological process.

Once the basic framework of qualitative forms of matter and their physical phase transformations is established, we are in a position to address the further development of physical nature that Hegel examines under the heading of “particular individuality ”. Here what lies at stake are the further differentiations of natural process which involve how physical process impacts upon mechanics and gravitational relations in general. This is the context within which specific gravity and qualitative relations of cohesion and elasticity come into play.

Specific gravity concerns the density of a material body and is a matter of physics rather than mechanics insofar as qualitative physical relations entail differences in density . Similarly, cohesion obtains a qualitative physical reality in so far as it involves more than the elementary singularity of a body that has a center of gravity through the coeval combination of repulsion and attraction. Qualitative physical relations allow for further natural features differentiating the adhesion, cohesion , and elasticity of bodies. Hegel presents specific gravity first, suggesting that differences in density do not themselves involve prior relations of adhesion, cohesion , and elasticity , but rather that the latter operate on the basis of physical relations that already possess a determinate specific gravity . We will have to examine what it is that is inherent in differences of specific gravity in contrast to what physical relations constitute the adhesion, cohesion , and elasticity of different bodies.

Of further concern will be the physical realities of sound and heat . In what respect are they physical processes that are not simply reducible to the motions of finite or absolute mechanics? These physical realities conclude what Hegel develops within the second of the three divisions of his conception of physics.

Moving from the “particular” to the “total free individuality ” of physical nature , we come to the inorganic configuration that natural entities can have. This involves the physical shape differentiating bodies, involving relations of electromagnetism that give bodies qualitatively distinct configurations, and entail the formation of crystals.

With these physical developments, bodies acquire particularizations that have specific ramifications for their relation with other physical processes. In this respect, Hegel will consider how the qualitative character of physical objects effects their interaction with light. This will involve transparency , the refraction of light, and the color of objects. Why are some objects transparent whereas others are not? Why does light get refracted in different ways as it passes through different materials? Why do things have different colors? All these matters involve light in connection with objects that are not just spatially determined, but qualitatively distinguished in respect to their physical constitution.

Similarly smell and taste , banished as non-objective affections of the subject by early modern philosophers through Kant, will now come into play as objective physical processes, rooted in the qualitative constitution of different things. What here lies at stake is not the psychological process of sensing smells and tastes, which is a topic for investigation within the philosophy of mind , but rather the physical conditions that enable something to have a smell and a taste . There is something physical at work here and we need to consider what it is, even when such physical realities occur without any sentient beings present to perceive them.

The physical reality of electricity must further be addressed, as a prelude to the final section of physics, which concerns chemical process. Unlike Kant, Hegel will not hold reason back from

thinking about galvanism, combustion, neutralizations, salts formations, and the dissociation of chemical substances. These are all the more important, for they provide us with the primordial soup from which life can be generated and conceived. With chemical process, we have everything that life is going to involve.

The preceding outline sketches an itinerary for understanding how the mechanics of matter and motion becomes supplemented by physical processes that provide the enabling conditions for life, and ultimately, for the intelligent life that can philosophize about nature . We now must examine what comes under each stage of this itinerary and whether its basic content and ordering is adequate.

7.2 Aristotle ’s Physics of Light

Hegel provides us with a wealth of physical processes to think through, and among them, we encounter many a topic that Aristotle also addresses. From the beginning, however, Hegel’s account stands apart. Although Aristotle has a few things to say about light, it is far from clear how he situates light within the processes of nature . Hegel, by contrast, emphatically presents light as the first physical reality to be considered as nature builds upon mechanics.

Whereas Hegel addresses light after absolute mechanics, Aristotle briefly considers light in his treatise on the soul, *De Anima*. There light comes up in a discussion of the senses and how they operate. Unlike early modern accounts of sensibility, Aristotle considers each sense in conjunction with the particular physical reality to which it relates.

By contrast, when Kant considers sensibility in the *Critique of Pure Reason*, he discusses space and time as forms of sensible intuition, but otherwise leaves out of account any determination of the different senses, let alone of the specific physical realities they sense. By contrast, in the *Metaphysical Foundations of Natural Science*, Kant does refer to one of the senses in analyzing the alleged distinction in how repulsion and attraction are experienced. Namely, Kant invokes the sense of touch as what makes matter empirically present. Matter is experienced as something tactile, something whose force of repulsion is felt immediately by touch as resisting the pressure of our own body . [5] In so doing, Kant does at least acknowledge the physical basis for touch by discussing the resistance offered by the material filling of space. Otherwise, however, there is no mention of the senses in Kantian pure mechanics , reflecting how it is limited to the motion of undifferentiated, rather than qualitatively distinguished matter.

A universe restricted to mechanism can hardly have room for either pole of sensation. On the one hand, the senses are endowments of an animal organism , whose internal teleology and centralized sensitivity and motility cannot be reduced to the external, form indifferent necessitations of efficient causality. On the other hand, the qualitative neutrality of mechanism ’s governance of undifferentiated matter cannot determine the qualitatively distinct physical features to which each sense responds.

Aristotle acknowledges that although there are physical features that only each sense can sense, there are material features (“movement, rest, number, figure, magnitude”) [6] that are sensed by all the senses, comprising the object of what he calls common sense. These material features end up being akin to what early modern philosophers and Kant take to be the truly objective features of reality, the spatiotemporal parameters of bodies, to which the so-called primary properties apply. Whereas the remaining secondary properties that qualitatively distinguish the things that occupy space here and now are dismissed as subjective affections, Aristotle , foreshadowing Hegel, grants these qualitative features a genuine physical reality. One can hear where something is, one can see where something is, one can touch it, smell it, and even taste it because there is something more at hand than the mere occupation of space through the dynamic combination of repulsion and attraction.

None of these physical realities can be granted any objective role in the foundational epistemology that Kant pioneers. Kant may not have any explanation of why our sensibility has no other universal forms than temporality and spatiality, but it is not hard to understand why he cannot acknowledge sight, hearing, smell, taste , and touch to be fundamental human senses. Insofar as possible objects of experience are to be determined by the structure of cognition, all that holds true of them universally must involve what pertains to objects no matter what they are.

Whereas spatiotemporal determinations apply to matter as such, the qualitative sensual properties are specific to the nature of different things. Moreover, although the knower must be able to apprehend space and time to experience anything at all, one can be blind or deaf or lack smell or taste or perhaps even touch and still have experience at least so long as one or more senses remain operative. Since foundational epistemology is concerned with possible objects of experience as they are determined by the universal structure of cognition, it can only admit the necessary objectivity of those specifications that any knower confronts, be one Helen Keller, a numb victim of leprosy, or someone with all five senses in healthy condition.

Nonetheless, since one cannot experience non-psychological objects without at least one sense being operative, a proper philosophical psychology can conceive the possible modes of sensation, which themselves presuppose a philosophy of nature that can transcend the limits of mechanics and conceive the physical properties that these modes sense.

Aristotle considers touch to be a basic sense without which none of the others could provide an objective apprehension. [7] Even if this is true, it does not mean that the physical properties sensed by touch are all primary. Certainly the dynamic occupation of space that Kant acknowledges to be sensed by touch has a primacy, since all matter must combine attraction and repulsion and have some degree of tangibility. Whether cohesion , adhesion, elasticity , and heat are all equally primary is something that the account of physics will clarify.

In *De Anima*, the physics of light comes into play in connection with analyzing sight. Aristotle recognizes that to deal with sight we have to understand visibility, which itself involves light. Aristotle characterizes the visible in terms of color and something else for which he has no single name. [8] The visible not only possesses color , but involves something that is the cause of visibility. For an object to have color , it must have a "power to set in movement what is actually transparent." [9] Light facilitates this power, which enables the color of the visible to manifest itself through what is transparent. This is why, Aristotle maintains, nothing is visible without the aid of light. [10]

This account suggests that the visible consists in a substance in which color inheres. Color provides the visible with the power to set in movement, that is, to alter what is actually transparent. The alteration of the transparent by which color enables the visible to be seen depends upon the help of light. The transparent, Aristotle explains, is not "visible in itself", but rather undergoes an alteration by which it "owes its visibility to the color of *something else*." [11]

How then does light come into play and what does it contribute? Something must have color to have the potential to be visible. Visibility becomes actual when what is transparent becomes visible by means of the color of what is itself thereby made visible. Something's visibility thus depends upon a transparent medium, which itself can only be a medium of visibility with the help of light. Aristotle presents us with four factors constitutive of visibility: something that has color , color itself, the transparent, and light. Color , as a feature of what has color , does not exist apart from a potentially visible substance. That which has color , color , and the transparent can be without light, lurking in darkness devoid of visibility. What about light? Can it be apart from what has color and the transparent? Or, does all light originate in self-illuminating bodies, either stars or objects undergoing light emitting processes other than nuclear fusion?

If light exists only in relation with what is colored and the transparent, then light depends upon the physical features that make matter colored and render the transparent something that conveys the color of something else.

Aristotle here introduces light in connection with physical features that Hegel brings into play when considering how physically differentiated matter interacts with light. In that context,

Hegel considers how the physical properties of matter give it color , make it transparent, translucent, or opaque, and affect how light is reflected from and refracted through it. When Hegel considers what is transparent, he acknowledges that transparent matter may be air (gas), water (liquid), or earth (solid). In each case, what makes a physical entity transparent is a special relation to light that has some external source. Consequently, the relation of physical materials to light coming from without presupposes the physical reality of the generation of light. Hegel offers a source of light in his account of the universal individualities of physical nature , where stars are conceived to be entities whose constitutive activity consists in none other than the production of light.

Whatever the source of light, the transparent is that which is visible by making manifest the color of something else. The transparent achieves this by allowing light to illuminate what has color . The activity of the transparent qua transparent thus involves light.

Where there is the power to have the activity of the transparent qua transparent there is also the potentiality of the privation of that power, the absence of its activation, which is darkness. [12] Light, Aristotle suggests provides the "'proper' color of things" [13] insofar as light enables color to manifest itself as it is in itself. This presumes that light has no color of its own that would affect the hue of what it illuminates. In other words, light does not illuminate itself, but only what it shines upon, including whatever might be the source from which it emanates.

Similarly, the transparent as such has no color of its own. If it did, it would be translucent, but not fully transparent. That is, the medium of illumination would color what it allows to be revealed, casting its own hue upon the color of what it allows to be visible. In other words, what has color is no longer transparent as such. Instead of being a pure medium of visibility that reveals only what it transmits, the colored, translucent factor shows itself along with what it allows to be visible. This is why Aristotle has told us that the transparent is not itself visible in virtue of itself, but visible only insofar as its makes manifest the color of something else.

Although gases, liquids, and solids can be transparent, does the colorlessness of both the transparent and pure light suggest that the activity of making visible the colored is nothing but light itself, which can perform its service without need of any additional transparent medium? Aristotle disputes that light can illuminate without a medium. He points to how the color of something cannot be perceived if it is placed in direct contact with eye. Although this suggests merely that vision is only possible at a distance, Aristotle concludes that sight "cannot be affected by the seen color itself," but "must be affected by what comes between." [14]

Aristotle has spoken of how the substance of light is something shared by terrestrial transparent materials and stars. Stars, however, are self-illuminating. This feature is highlighted by Plato in the analogy of the good to the sun in Book VII of the *Republic*, where it serves to illustrate how the good not only makes knowable the true nature of things by being the source of the knower, the object, and the manifestation of the object to the knower, but further manifests the form of the good to our reason. [15] Similarly, stars and any other source of light are self-illuminating, manifesting themselves while casting light upon other bodies.

Aristotle does connect light to fire, observing that light "exists whenever the potentially transparent is excited to actuality by the influence of fire or by something resembling the 'uppermost body '" of the heavens, namely, a star . [16] Fire plays this initiating role because it "contains something which is one and the same with the substance in question." [17] By way of explanation, Aristotle notes that "light is neither fire nor any kind whatsoever of body nor an efflux from any kind of body " but rather, "the presence of fire or something resembling fire in what is transparent". [18]

Aristotle ’s introduction of fire gives us a more concrete physical account of light and illumination. First of all we have color which itself has the power to set in motion what is transparent. As long as we have substances that are transparent, which share the kind of stuff through which stars can shine, color can emerge from darkness with the help of light. Although light is not fire, the presence of fire in the transparent constitutes the helping hand of light. The potentially transparent substance becomes actually transparent through the influence of fire, which allows the transparent to be the activity of light that manifests the color of something else. Fire is needed to generate light and make transparency actual, allowing something to be visible and make light itself visible. When, however, Aristotle maintains that fire contains something which is the same with the substance in question, it seems that fire and light might actually be the same. After all, the substance of the stars involves fire and just as much possesses the substance shared with what is transparent. Of course, if fire allows transparent substance to activate itself, then the stars, having fire, would be self-illuminating.

The fire of stars, however, is not equivalent to terrestrial fire that might be identified with the chemical process of combustion, which gives off heat and light by altering molecular bonds. If fire is identified as an element, not in the atomic chemical sense of the Periodic Table , but as a phase of matter, then the connection with light takes on a different character. Might the element of fire, that is, the state of matter that might be identified with plasma , have a physical connection with light emission? Is this exhibited in the nuclear furnace of stars, where atomic fusion may generate plasma , rather than liquid , solid , or gaseous states of matter?

Although fire and light may be intimately connected, Aristotle maintains that light is neither fire nor any kind of body nor an efflux from any kind of body . Aristotle distinguishes fire from light, noting that whereas color cannot be visible without light, fire is visible “both in darkness and in light.” [19] On the other hand, light cannot be an efflux from any kind of body because then it would be the same thing as a body , since an efflux is an emission from a body . [20] How then do we make sense of the relation between color , fire, and light?

Light is something resembling fire in what is transparent. Light is in the transparent, but it is not itself a body . Light is rather the activity of the transparent, which involves the presence of fire or the presence of something resembling fire. This is why light cannot be a body , for if it were, there would be two bodies in the same place : namely what is transparent and light. [21]

It is worth considering the kind of things from which Aristotle differentiates light and what might be their contemporary counterparts. Aristotle has distinguished light from fire, which is one of the elements. Since Aristotle has dismissed the possibility of light being a material substance or an efflux from one, light can be neither an element, nor a particular body nor an emission from any particular body . Light cannot then be a photon or a particle of any sort.

Aristotle specifically criticizes Empedocles for treating light as if it traveled from an object emitting light to something that is receiving or reflecting it. Aristotle denies Empedocles’ account in face of certain facts. First of all, if light were traveling, it would take some time to arrive, but it appears instantaneous. Second, we don’t observe light somewhere before it reaches its destination. Rather, light and the making visible of something colored is coincident. [22] So light would be neither a traveling particle nor an emanating wave, even though a wave can be a movement in a medium, rather than a voyager across empty space.

Light instead just somehow facilitates the process whereby the transparent, which is in itself colorless, takes on the color of something else. Sound , smell, taste , and touch operate, Aristotle maintains, analogously. [23] Each involves a medium that is itself devoid of noise, odor , savor, and tactile feel, but which takes on the sound , smell, taste , and touch of what possesses the

power to affect some particular sense. The medium, in the case of visibility, the transparent, is a substance that undergoes the alteration of manifesting color from elsewhere and light is the activity by which this alteration occurs.

There is a certain ambiguity regarding what it means for the transparent to make visible the color of something else. Does the transparent itself take on the color in question or does it simply affect the sense organ it reaches so as to permit it to sense that color ? The object with color can be both in darkness and light, just as can the transparent itself. With light, the colored object becomes visible and the transparent medium “takes on” the color of that object to allow sight to see what it cannot if it had to make direct contact with the colored object. Light does not here figure as an independent entity, a substance. Color supposedly has the power to set in movement that which is transparent, and light makes actual the reality of the transparent as taking on the color of something else. Since light is tied to the alteration the transparent undergoes, and by extension, the alteration something colored undergoes to become visible, it is not a substance that might independently move and pass through empty space. Light instead figures as the activity of a certain kind of substance, shared by what is transparent, and connected to fire.

This might seem at odds with Aristotle ’s own observation that something colored placed in immediate contact with the eye cannot be seen. That observation might suggest that visibility operates only at a distance and that light could be a substance traversing empty space, rather than the activity of a transparent medium. When Aristotle dismisses Democritus for suggesting that “if the interspace were empty one could distinctly see an ant on the vault of the sky,” [24] Aristotle brings to bear considerations that harken back to his argument against inertia . Although an impacted object continues in motion after contact has been broken, Aristotle suggested that inflowing air continues to push the object onward. Similarly, light transmits color at a distance through the intervening activation of a continuous transparent medium. On this basis, light constitutes a condition for allowing the visible to be seen by being the activity of the transparent medium as transparent, as taking on the color of something else. This “taking on color ” is a movement, for it involves an alteration whereby the potentially transparent medium manifests itself as transparent by letting color “pass” through it. Color is “communicated” through the change from potential to actual transparency .

What makes something transparent, be it potentially or actually? Aristotle associates transparency with fire, in connection with how fire can be seen in darkness. In the absence of light, without either a terrestrial light turned on or the sun shining, fire is still visible. Fire makes what is potentially transparent actually transparent. Fire activates the activity of transparency . Fire is required because the activity of light is not self-engendering. It requires something else, like motion in general. After all, the movement actualizing the transparent as transparent is a kind of motion, an alteration. It is a motion of the substance of a medium and like every other motion, it is not self-moving. Where does it come from? Aristotle refers to the eternal upper body , the stellar celestial substance, which has either fire or something like it in itself. It always has light, exhibiting the color of the fire which Aristotle associates with the color of its celestial light. The eternal upper body has a substance whose activity is light and that substance is the same as what air and water contain in order to be transparent and take on the color of other things. [25] Transparency may need light to be actual, but does the substance in transparent air and water generate light in the same way as does the substance of a star ?

Furthermore, is the activity of light of the eternal upper body something self-moving in violation of Aristotle ’s prohibition of self-motion? Do the stars not illuminate themselves, which is to say, do they not take on a color of their own? If, however, the light emitting activity of the

stars is moved by something else, what can it be? The eternal circular motion of celestial bodies may be imparted by the unmoved mover, but does this itself generate the further activity of light? Can the physical process of light be reduced to or derived from mere locomotion ? Or is light at hand because the eternal upper body is inflamed with an eternal fire? Can eternal circular motion continually produce this eternal fire, and with it, stellar light? Are there not, however, celestial bodies that are planets, satellites, and comets, rather than stars?

In any event, can light be derived from the element of fire? Aristotle will distinguish the four elements (earth, water, air, and fire) in terms of two pairs of contraries: wet and dry, on the one hand, and hot and cold on the other. Whereas earth is dry and cold, water is wet and cold, and air is wet and hot, fire is dry and hot. Do fire's dryness and heat suffice to account for light? Aristotle himself admits of phosphorescent substances (e.g. "fungi, horns, heads, scales, and eyes of fish"), [26] which emit light while being cool, if not moist.

To resolve the quandaries raised by Aristotle 's physics of light, we must better understand the different states of matter , the nature of heat , and, of course, light itself.

7.3 Hegel's Account of Light

Aristotle account of light raises the question of how light originates. Rejecting self-motion and privileging locomotion as the motion from which all other changes derive, Aristotle roots all change in an unmoved mover who eternally engenders an equally eternal circulation rotation of eternal heavenly bodies, whose inclination to the terrestrial sphere accounts for the production of earthly irregular movements. Aristotle associates an eternal fire with stars and this brings light into continuous activity, actualizing the transparent medium as transparent. What Aristotle does not explain is how celestial locomotion is connected with fire and light, nor does he adequately clarify how fire and light are related.

Hegel's understanding of absolute mechanics frees nature of any dependence upon an unmoved mover, but his development of physical process still proceeds on the basis of matter in motion and the astronomical framework of a self-sustaining gravitational system. Hegel begins the development of physical process by addressing light in general, before considering the different states of matter , to which the "element" of "fire" can be ascribed. Nonetheless, Hegel does consider light as predicated upon matter. In various respects, light cannot be nor be conceived apart from matter and the gravitational system of bodies. This is manifest in how Hegel develops light in connection with the "universal individuality " of physically distinguished bodies, which also play the role of gravitational center in the system of free mechanism . Light is thereby rooted in self-illuminating bodies, which are astrophysically distinguished by their central role in self-moving gravitational systems.

Why should light emission go together with being the hub of a planetary system? Alternately, why should being a "dark", "reflective" body go together with orbiting a star ? What must be invoked to ground how a central body can be self-illuminating?

The modern explanation is something of which Hegel has little inkling. Lacking any idea of nuclear fusion, Hegel is in no position to show that a central body could have sufficient matter to engender gravitational forces compressing it to the threshold of fusing atomic nuclei and releasing vast amounts of energy , much of which takes the form of light. Smaller bodies, whose relatively lesser mass would leave them orbiting a central body , would lack sufficient matter to ignite nuclear fusion. Accordingly, absolute mechanics would provide for the emergence of light in connection with the physical processes that differentiate the astrophysical bodies of gravitational systems. It would do so, provided that matter involves the basic qualitative difference with which nuclear physics can be in nature and in theory. Namely, matter must not only be individuated into separate bodies through universal forces of attraction and repulsion, but distinct bodies must be further differentiated by the most minimal qualification possible. This is polar opposition, by which a body or particle exerts a force in opposition to that of another, rendering one negative in charge and the other positive in charge. Since each is what the other is not, it makes no difference which is called negative and which positive. Once, however, undifferentiated matter complements its constitutive attractive and repulsive force fields with negative and positive polarity , physical processes have resources sufficient to generate a qualitative world, from which chemistry and life can follow. [27]

7.4 Light and Qualitative Physics

In moving from mechanics to physics, we must begin by addressing the most rudimentary qualitative distinctions of matter and the elementary physical processes in which they figure. Hegel meets this challenge by conceiving the basic physical realities as free, independent bodies. Consequently, when Hegel begins with light as elementary physical process, he conceives a certain kind of body specifically associated with light. Thanks to nuclear physics, it is comprehensible how light and stars are connected and how central bodies in gravitational systems are likely to emit light, in contrast to the dark matter orbiting them.

In paragraph 275 of *The Philosophy of Nature* Hegel presents a very cryptic general designation of light, defined in relation to matter. Light, he explains, is the "existent, universal *self* of matter." [28] This comprises the first, most minimally qualified specification of matter, where matter is "pure identity-with-self" in its "first, still quite abstract *manifestation*." [29] Light is that by which matter manifests its pure self-identity. Light illuminates matter, presenting it as it is, with no further appreciable modification. In this way, matter's manifestation in light is "still quite abstract" insofar as light lets matter reveal itself in general, rather than in some concrete manner specific to what makes it manifest. Light, however, is not something purely theoretical, as much as its "abstract manifestation" may make sight the most theoretical of the senses. Light is still a physical reality, which can thus comprise the "existent, universal *self* of matter" insofar as light gives existence to the manifestation of the identity of matter of any sort so long as it is subject to illumination. In its illuminated manifestation, matter is at one with itself without undergoing any other material transformation. Reflection enters in along with self-identity, for matter reflects itself in whatever light makes it manifest.

The abstract character of matter's manifestation in light applies to matter that, at this primary stage in physical process, is itself very abstractly determined. Without any further qualitative determinations, matter simply consists of individual bodies occupying specific volumes with determinate masses, measured by the velocity and trajectory of their locomotions. Light, to begin with, has thus something very abstract to manifest. There are bodies with a certain shape and amount of matter moving relative to one another, some following orbital paths, others falling to a central body , and others making inertial impacts. Such is the minimal self-identity of matter that light exhibits in general. Further features such as specific gravity and crystalline structure will themselves depend upon physical processes where electromagnetic polarity qualitatively shapes the composition of material bodies and affects their reflection and transmission of light. At this stage, bodies have a center of gravity and move and now take on the further aspect of manifesting themselves as self-identical in the illumination of light. Just as all bodies are subject to gravitational attraction, so all bodies are subject to the physical process of illumination once gravitational systems have given rise to the "universal individuality " of light emitting bodies.

Light, in this connection has no character apart from the process with which it illuminates matter. What would pure light be that simply infuses itself without illuminating matter? Could it be distinguished from darkness, the sheer absence of light? As Hegel suggests, pure light is just an undifferentiated dispersal in which bodies could become manifest, but in their absence, pure light is just as empty as pure darkness. [30] Light is something physical and not equivalent to empty space, but "light as such is invisible" without encountering something different from itself, namely matter. [31] Only when there is some meeting of light and dark, some rendez-vous of light with something other, does light manifest itself determinately in its abstract manifestation

of matter's self-identity.

Light is thus itself determinately manifest only in conjunction with matter. Although this relation does not require any medium to illuminate the visible, something similar is anticipated by Aristotle 's conception that light is the activity of the transparent enabling the transparent to manifest the color of something else.

Unlike Aristotle , Hegel is willing to grant that light disseminates itself through empty space, adding to the space it traverse not matter, but something physical that only gains determinate manifestation in relating to matter. Light is thus ideally physical, giving matter qualitative determination without being material itself, just as space and time are ideally natural, giving nature an immaterial determination from out of which matter and motion are constituted. Is light then just pure electromagnetic energy , devoid of mass , even though energy may be transformed into matter?

Further, just as space and time contain matter, so light encompasses matter within the domain of its illumination. Hegel describes light as "the self-contained totality of matter … actuality as a transparent possibility." [32] Light may not fill space with moving forces of attraction and repulsion, like matter does, but it disperses as a field within which matter can physically manifest itself without having to exert or be subject to additional force.

Einstein will question the reality of empty space by maintaining that electromagnetic fields , as well as gravitational fields , have a physical reality, whose energy is convertible to matter. Nonetheless, insofar as the dynamic constitution of matter through the moving forces of attraction and repulsion can be distinguished from the emanation of electromagnetic, as well as gravitational fields, space filled with matter can still be distinguished from space filled with fields of energy . Although there may be no space "empty of field", as Einstein points out, there can be space unoccupied by material bodies. [33]

What does light make manifest? Minimally, light exhibits the spatial boundary of bodies, if they obstruct its dispersion. In this bare silhouetting, light discloses nothing but a body 's occupation of space here and now. If, alternately, light passes through a body that is not completely transparent, both the body 's surface and translucent interior become visible. If, instead light is reflected in varying degrees off the surface of an opaque body , the body shows its surface with color variations. Finally, if light is emitted from a self-illuminating body , that body 's source of light is itself exposed. All these variations depend upon the physical composition and geometric structure of a body , and until qualitative physical differences are determined, light's specific relation to them cannot be adequately addressed.

What about light itself? It is not equivalent to empty space, through which it disseminates itself unless obstructed by matter. Light, however, is not a physical substance nor a physical medium. How then do we distinguish empty and filled space without light from empty and filled space containing light? Utterly empty space, Hegel has noted, is indistinguishably dark or light since pure light is just as null as pure darkness. Space with bodies in a void is evidently different when lit as opposed to when dark, but how can the presence of light be identified?

In the addition to paragraph 275 of the *Philosophy of Nature* , Hegel offers three successive determinations that clarify what is basic to light.

First, he tells us that light is a wholly universal manifestation. Light is, in and of itself, devoid of any particularization. In contrast to light that is related to a specific physical reality, light per se does not differentiate itself—e.g. it does not break up into the spectrum produced by its passage through a prism. It is devoid of any specific features; it is just that in which any matter can make itself manifest.

Secondly, light extends itself absolutely in space, unless some opaque entity obstructs its way. Light does not limit its own dispersal. Rather, light disseminates in a completely general distribution. In and of itself, light disperses itself without limit, but to take on any determinate character, it must arrive at some limit. Otherwise, it has no specific content. Light's sheer manifesting of matter obtains determination by reaching some boundary, some limit, comprised of what light is not, namely something that is not lit, something that does not illuminate itself. Such dark matter needs light to show itself in an ideal way, as opposed to the real manner of gravity and impulse. Conversely, unimpeded light does not manifest anything, other than what might distinguish its source. As Hegel notes, in pure light, nothing is seen. [34] There is no difference between sheer darkness and sheer light. Only if light and dark are combined can there be any determinate light. That requires some material body to provide that opposition and it will provide what is not itself light. Empty space cannot be illuminated, for it provides nothing to bound light's emission. Only matter can enable light to illuminate and obtain determinacy.

These are very minimal features. Light is simply universal in character with no more specific features in and of itself. It disperses itself infinitely and without bearing any mass . It only becomes determinate when it reaches some limit, something other than itself, namely, matter that is not self-illuminating. How then does light make manifest matter and thereby manifest itself? Insofar as light is the physical factor by which matter manifests itself without undergoing any appreciable spatiotemporal or material alteration, [35] matter remains identical to itself in its illumination. Light provides a completely formal manifestation, leaving otherwise unchanged what it exhibits.

There must, however, be some basis for light, some subject of light. Light requires some physical source, something that is in and of itself an emitter of light. Light is not generated by space and time , nor the pure mechanics of matter in motion. Nonetheless, as Hegel acknowledges, there is a body whose special role in absolute mechanics is associated with the character being the source of illumination, of being a self-illuminating body . As self-illuminating, such a light emitting body does not produce merely general light that is indistinguishable from darkness. Rather, as an individual body with the physical character of emitting light, it constitutes a self-illuminating mass whose light exhibits its own material being. Its light is as individual as itself, although it shines upon other dark bodies in the formal manner that allows them to be self-identical as an individual limit to light.

It is important to keep in mind that light, as an elementary physical process, does not yet involve the type of differentiations of types of matter that allow for chemical processes, like combustion, that may themselves emit light. Here, the source of light is a central body that illuminates itself without depending upon chemical process. Hegel associates this original source of light with the sun or, generally, with objects that play the role of the center of gravity in the self-moving gravitational system of absolute mechanics. Hegel does not have much to say about how being the center of gravitational attraction is tied to being an emitter of light. One could argue that the bodies which are the center of gravitational systems are going to be self-illuminating owing to the ignition of atomic fusion caused by sufficient gravitational compression of their larger mass .

Hegel does point to one consideration for how one can account for the production of light by the central body . He describes how light might be thought of as being generated in stars, including our own sun , due to a mechanical processes, namely, their axial rotation. The stars and the sun are rotating around their own center and this generates internal friction, which engenders a "process of phosphorescence which emits light." [36] In this rotation, solar system central bodies

exhibit the special self-relating motion whose physical correlate and product is the self-illumination of light emitting masses.

Hegel's appeal to stellar rotation as a source of light calls for further explanation. What seems to connect rotational friction and light emission is heat and, if we were to invoke the states of matter or "elements", fire. This would bring us back to Aristotle 's account of the elements and their primary qualities. Hegel, however, points out that such "finite" sources of light as the combustion of earthly fire involve physical particularizations of matter that themselves presuppose the elementary physical process of light and solar emanation. [37] The earthly processes of fire, combustion, and phosphorescence will be shown to depend upon the more basic physical process of light and, more generally, electromagnetic radiation and the polarity of charge making possible atomic and molecular organization. The association of original light emission with stellar bodies itself indicates that specifically terrestrial processes cannot play a role. We must distinguish the original light from the earthly light associated with heat and fire. If light were to be generated from these earthly processes, there would have to be an account of heat , combustion, and fire, that could be given prior to light and the physical process of stellar bodies. Heat , understood as the kinetic motion of atoms and molecules, already involves electromagnetic polar relations. Moreover, identifying heat simply in terms of kinetic motion leaves unexplained how it is connected to the special physical properties of light.

Striking, in this connection, is how light illuminates other things. Light illuminates without requiring any appreciable locomotion or communication of moving force. Recent scientific observation does suggest that light exerts a certain, albeit, relatively minute pressure, even though, light is considered to be devoid of any mass . Light then remains the peculiar entity that does something to matter, while having something immaterial, ideal, about itself. Although light is devoid of mass , it has velocity. It transmits itself without requiring a medium, although it exhibits itself only in terms of either its original stellar source or the "dark" matter that it illuminates. Light itself is weightless. It is just this pure making manifest of matter and yet this pure making manifest of matter is also rooted in matter that occupies the position of central body in the gravitational system of absolute mechanics. When matter is lit, it is not in the same physical state as being dark. Its illumination comprises a physical relation to other entities.

In the remark to paragraph 276 of the *Philosophy of Nature* , [38] Hegel inveighs against characterizing light in terms of rays or particles or bundles. He grants that light propagates itself infinitely in space, so long as nothing impedes its travel. He acknowledges that as soon as light meets some limiting matter, it itself appears in the self-manifestation of the illuminated body . Why, then, does he reject thinking about light as consisting of rays, a representation that seems to fit these features?

A ray of light particles has motion in one direction and as rays of light disseminate from their source, their distance from one another increases, leaving more and more of space unilluminated by their transmission. Light, however, disperses in a continuous field that illuminates without any gaps, so long as no bodies impede its transmission. This continuous extension poses problems for any conception of light that conceives it to consist of discrete particles, a conception which can go together with the notion that light emission consists in a dispersion of rays.

These difficulties might suggest that light instead consists of waves, whose continuous transmission can illuminate without gaps. Hegel, however, equally rejects thinking about light as involving waves. Wave transmission ordinarily entails a substance through which the wave travels. This substance could be considered a medium separate from light or a substance in which

light itself consists. Light, however, emanates without need of any separate medium. Unlike sound , and perhaps unlike the kinetic energy of heat , light can disperse through empty space and illuminate across physical voids. On the other hand, light has no mass , no material substance of its own. Light relates to matter in general and as such it cannot be a particular type of matter. Just as space and time are immaterial factors constitutive of the material dynamics of pure mechanics , so light is the ideal physical factor on the basis of which all further physical processes develop. Light is no more wave than particle .

Although light emission may consist neither in rays of particles or waves spreading through a medium or a light substance, light's manifestation in the manifestation of matter becomes more concretely determined in a variety of ways. First of all, there is the question of the material basis of the source of light, namely the physical constitution of an original self-illuminating body . Then there is the further question of how light is manifest in illuminating "dark" matter.

The most basic, minimal illumination by light is of dark matter in general, that is, matter that is not itself a source of light but otherwise is not further differentiated. How is such undifferentiated dark matter made manifest by light?

Minimally, light illuminates the outer shape , the surface of undifferentiated dark matter. This basic illumination does not involve any basis for color distinctions or any other optical phenomena. All that is manifest is the surface, the determinate boundary by which light illumination itself becomes determinate. The surface provides the limitation by which there is neither pure light nor pure darkness, but something in between.

The surface, however, is itself susceptible of material differences that take on physical ramifications in relation to light. If the surface is completely undifferentiated, it opposes to light a completely smooth boundary. In that case, where the surface has no differentiations of its own, the illumination by light will manifest the light itself, reflecting the light without modification, albeit within the boundary of the surface shape of the reflecting body . The perfectly smooth body will reflect the light that has come to it, without imparting the body 's own qualitative differentiations, such as color would involve.

In order for the visibility of the illuminated body to be determinate in its own right, and not just reflect its light source, the body 's surface must not be perfectly uniform, but have some specific variation. Such variation need not engender color differences, for the most basic surface irregularity can impede complete reflectivity, without producing color . There can be a determinate visibility which shows surface features of the object without color , just as there can be color blind vision that sees objects whose surfaces are not pure mirrors. A body can manifest itself as a definite entity, rather than a pure reflector of light, provided its surface has some variation. That is the minimal physical process at hand.

The definite manifestation of an illuminated body is thus something more primary than color visibility. In this connection, Hegel points to two basic principles of the reflection of light that apply to the most rudimentary geometric articulation of an illuminated body . He observes that the reflection of light will proceed with equal angles of incidence and reflection and do so in the same plane. [39] Although Hegel does not explain why that is the case, since the object of illumination is just an undifferentiated surface, it presents a plane, offering no physical reason for light to diverge from a simple reflection with equal angles. If, however, the surface is irregular, with multiple surface oppositions, there will be multiple reflections. This can engender polarizations, where, as Hegel discusses, [40] the plane of refraction gets altered so that the light is not visible unless the angle is altered in the manner in which the manipulation of polarized lenses changes how light gets transmitted.

What here is at stake are very rudimentary determinations of how light manifests itself on material bodies, whose surface exhibits merely geometric specifications of shape involving planes. The surfaces of lit bodies are not yet further differentiated in terms of the physical properties that allow for differences of translucency , transparency , or color . Hegel will address these factors later when the development of physical process establishes further structures of matter that enable light to interact with bodies in these more concrete ways.

What Hegel here does see fit to develop is how the transmission of light takes place in time . He does regard the dispersal of light to take time rather than being instantaneous. Someday, Hegel predicts, astronomers, will find out the stellar light they are observing has actually been transmitted five hundred years ago, [41] for light, as fast as it may go, still takes time to traverse interstellar space. There is an alteration when things become illuminated. It takes some time . There is a separation between bodies, which light must traverse at a speed that is finite. [42]

Here, in the basic, most elementary account of light, objects manifest themselves in terms of their spatiality, as bodies with shape located in a determinate place with respect to the source of their illumination. Nothing more is available to come into play. The talk of color requires more physical resources, as do considerations of relative refraction , translucency , or transparency . Nonetheless, one physical distinction is already at hand, that distinguishing the source of light, the self-illuminating body , from the dark matter it lights. That distinction is basic to the propagation and illumination of light.

The *Book of Genesis* pictures something analogous. At the beginning there is light, resting on a distinction between a self-illuminating body and bodies that are not. There cannot be light without matter and the physical differentiation of self-illuminating bodies and bodies that are lit. Light is something that is exhibited in matter, as a physical qualification of matter, a way in which matter manifests itself without wielding moving forces as occurs in gravitational or inertial interaction.

Could any other physical features be at hand without light and light emitting and lit bodies being present? Why is light physically fundamental? Could there be a universe in which there is no light but all sorts of other physical processes? Could there be a dark cosmos with atomic and molecular interactions and everything from weather to vulcanism?

Thanks to light, material bodies present themselves in a formal self-identity, in a manifest spatial outwardness. It might seem peculiar that Hegel immediately follows his account of light and self-illuminating bodies with a physical consideration of “the bodies of opposition”—comets and the satellites of a planetary body , as if to present a physical process that supervenes upon their role in the gravitational system of absolute mechanics. [43] Then, under the rubric of “the body of individuality ”, he introduces the earth, or, more generally, planetary bodies, as bearers of a distinct realm of physical process. [44]

What are the physical determinations of the “bodies of opposition” and the “body of individuality ” that may presuppose, but go beyond their roles in the mechanics of the solar system ?

Hegel distinguishes moons and comets here in terms of the rigidity of the former and the dissolution to which the latter is subject. [45] These contrasting principles of rigidity and dissolution impart a qualitative physical differentiation that involves more than the mechanical difference in their orbits. Hegel ascribes both these features to the earth, which contains them as elements of its unitary process. [46] The moon is like the earth to the extent that it is rigid, but otherwise, the moon lacks every other terrestrial feature beyond our planet ’s rigid, rocky inert ball of matter . The comet possesses the rest, namely water and some atmosphere. These

characterizations involve physical differences such as Aristotle introduced in his account of the fundamental elements, which consist in states of matter : namely, solid , liquid , and air.

Why should such terms now come into play? We know the moon , like the earth, is not self-illuminating. Hegel, however, is going to focus on the earth as the setting for the development of all of the further features of nature . Although one might speak about nature in general having subsequent specifications, including chemistry and life, they are not going to be found on stars, nor on a comet or a moon like our own. Only in the planetary realm will the full realization of nature ’s development take place . Is this the reason for distinguishing kinds of bodies before developing the further physical processes? Are planetary bodies the concrete natural settings presupposed by all that follows? Is physical process thereby fundamentally astrophysical in character?

Notes

1. Hegel, *Philosophy of Nature* , §273, p. 85.

2. Hegel, *Philosophy of Nature* , §274, p. 86.

3. Hegel, *Philosophy of Nature* , §281, p. 105.

4. Hegel, *Philosophy of Nature* , §286, p. 113.

5. Kant, *Metaphysical Foundations of Natural Science*, 510, pp. 47–48.

6. Aristotle , *On the Soul*, Book II, Chap. 6, 418a18, in *The Complete Works of Aristotle* , Volume I, p. 665.

7. Aristotle , *On the Soul*, Book II, Chap. 2, 413b4, in *The Complete Works of Aristotle* , Volume I, p. 658.

8. Aristotle , *On the Soul*, Book II, Chap. 7, 418a26–27, in *The Complete Works of Aristotle* , Volume I, p. 665.

9. Aristotle , *On the Soul*, Book II, Chap. 7, 418b1, in *The Complete Works of Aristotle* , Volume I, p. 666.

10. Aristotle , *On the Soul*, Book II, Chap. 7, 418b2, in *The Complete Works of Aristotle* , Volume I, p. 666.

11. Aristotle , *On the Soul*, Book II, Chap. 7, 418b5–6, in *The Complete Works of Aristotle* , Volume I, p. 666.

12. Darkness, Aristotle observes, is “the same as what is transparent, when it is potentially, not

of course when it is actually transparent". See Aristotle , *On the Soul*, Book II, Chap. 7, 418B29–31, in *The Complete Works of Aristotle* , Volume I, p. 666.

13. Aristotle , *On the Soul*, Book II, Chap. 7, 419a2, in *The Complete Works of Aristotle* , Volume I, p. 666.

14. Aristotle , *On the Soul*, Book II, Chap. 7, 419a18–19, in *The Complete Works of Aristotle* , Volume I, p. 667

15. Plato , *Republic*, Book VI, 508b–e, in Plato , *Complete Works*, p. 1129.

16. Aristotle , *On the Soul*, Book II, Chap. 7, 418b11–13, in *The Complete Works of Aristotle* , Volume I, p. 666.

17. Aristotle , *On the Soul*, Book II, Chap. 7, 418b13, in *The Complete Works of Aristotle* , Volume I, p. 666.

18. Aristotle , *On the Soul*, Book II, Chap. 7, 418b14–17, in *The Complete Works of Aristotle* , Volume I, p. 666.

19. Aristotle , *On the Soul*, Book II, Chap. 7, 419a23, in *The Complete Works of Aristotle* , Volume I, p. 667.

20. Aristotle , *On the Soul*, Book II, Chap. 7, 418b15–16, in *The Complete Works of Aristotle* , Volume I, p. 666.

21. Aristotle , *On the Soul*, Book II, Chap. 7, 418b18, in *The Complete Works of Aristotle* , Volume I, p. 666.

22. Aristotle , *On the Soul*, Book II, Chap. 7, 418b21–27, in *The Complete Works of Aristotle* , Volume I, p. 666.

23. Aristotle , *On the Soul*, Book II, Chap. 7, 419a25–419b2, in *The Complete Works of Aristotle* , Volume I, p. 667.

24. Aristotle , *On the Soul*, Book II, Chap. 7, 419a15–17, in *The Complete Works of Aristotle* , Volume I, p. 667.

25. Aristotle , *On the Soul*, Book II, Chap. 7, 418b8–13, in *The Complete Works of Aristotle* , Volume I, p. 666.

26. Aristotle , *On the Soul*, Book II, Chap. 7, 419a4–5, in *The Complete Works of Aristotle* , Volume I, p. 666.

27. The emission of light from nuclear fusion rests not only upon electromagnetic polarity , but upon the convertibility of matter and energy . Significantly, Einstein arrives at his $E = mc^2$ equation by considering how the empirically uncovered inability of material bodies to attain the speed of light *in vacuo* requires, as their relative velocity approaches that of light, not only the dilation of time and the contraction of bodily length, but also the increase in bodies' inertia or mass , making it ever more difficult to accelerate them further. This connection between kinetic energy and mass thus presupposes light, as do all the modifications of space and time that Special Relativity entails. Heisenberg points out these implications in his *Physics and Philosophy*, p. 89.

28. Hegel, *Philosophy of Nature* , §275, p. 87.

29. Hegel, *Philosophy of Nature* , §275, p. 87.

30. Hegel, *Philosophy of Nature* , Zusatz to §275, p. 89.

31. Hegel, *Philosophy of Nature* , Zusatz to §275, p. 89.

32. Hegel, *Philosophy of Nature* , Zusatz to §275, p. 87.

33. See Einstein, *Relativity: The Special and the General Theory*, pp. 176–177.

34. Hegel, *Philosophy of Nature* , Zusatz to §275, p. 89.

35. The photoelectric effect is an exception to this "formal" manifestation of light.

36. Hegel, *Philosophy of Nature* , Zusatz to §275, p. 90.

37. Hegel, *Philosophy of Nature* , Zusatz to §275, p. 90.

38. Hegel, *Philosophy of Nature* , Remark to §276, pp. 92–93.

39. Hegel, *Philosophy of Nature* , §278, p. 96.

40. Hegel, *Philosophy of Nature* , Remark to §278, pp. 96–97.

41. Hegel, *Philosophy of Nature* , Zusatz to §276, p. 94.

42. By contrast, Hegel develops gravitational attraction as initially involving an instantaneous action at a distance. Einstein will call into question any instantaneous action at a distance owing both to how time gets differently determined in different inertial frames of reference,

the more their relative velocity approaches the speed of light, and to how no physical interaction can occur at greater velocity than light speed. Einstein's embrace of the relativity of simultaneity rests upon light and the limit of its velocity. If, however, gravity first develops through the dynamic constitution of matter, where physical differentiations are not yet at hand, the complications predicated upon light are still not operative. See Einstein, *Relativity: The Special and the General Theory*, pp. 29–31, 53.

43. Hegel, *Philosophy of Nature* , §279, p. 99.

44. Hegel, *Philosophy of Nature* , §280, p. 103.

45. Hegel, *Philosophy of Nature* , §279, p. 99.

46. Hegel, *Philosophy of Nature* , Zusatz to §280, p. 104.

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8. The Physical States of Matter

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Whereas Kant generally limits the philosophy of Nature to the mechanism of matter in motion, Aristotle and Hegel both develop a physics differentiating basic elements whose process of transformation into one another appears to be irreducible to mechanism . In the “General Remark to Dynamics” in the *Metaphysical Foundations of Natural Science*, however, Kant discusses features of matter that seem to address physical forms distinguishing states of matter. [1] The nature of physical states of matter is illuminated by examining Kant’s remarks in contrast to the analogous conceptions developed by Aristotle and Hegel.

8.1 The States of Matter

Aristotle and Hegel both distinguish four so-called fundamental physical elements , identifying them as air, fire, water, and earth. Both thinkers conceive them to be forms of matter that transform themselves into one another. For this reason these “elements” correspond to the general states or phases of matter that might today be identified as gaseous, plasma , liquid and solid . They must not be confused with the “elements” of the Periodic Table , distinguished in terms of atomic structure, which bears upon molecular relationships and chemistry.

Hegel’s account of the physical types of bodies, stellar, lunar, comets, and planetary, is not unrelated to the elements insofar as stars may contain plasma (and perhaps gas , but not liquids or solids), moons may contain just solids, comets may contain liquid and gas , and planets may contain all four states of matter. Similarly, the more basic distinction between self-illuminating and dark matter seems to differentiate bodies of plasma (fire) from bodies of gas , liquid , and solid matter. By contrast the opposition of matter and antimatter has no determinate relation to the phases of matter, since matter and antimatter differ in terms of the contrary electric charge of their atomic particles, which may be present whether or not matter and antimatter are solid , liquid , gaseous, or plasma .

Although the basic process of light may end up involving bodies in different states of matter , and the individual types of astronomical bodies in solar systems may equally host different distributions of these states, what distinguishes these phases of matter is something that must be determined in its own right.

Do we need to introduce the charge polarity basic to electromagnetic phenomena in order to distinguish the phases of matter? If light is itself electromagnetic, then the light process already gives us this physical resource with which to determine the states of matter. Electromagnetic radiation will entail magnetic fields and electricity, which Hegel, for one, will address long after the basic light process is determined. Must light’s formal manifestation of matter involve the negative and positive charge polarity of electromagnetism ? To consider such physical realities we need to have at our disposable matter that contains not just the attractive and repulsive forces constitutive of material extension and gravity , but the further distinction between material bodies of opposite charges.

Before tackling these questions, it is worth taking note of some empirical information concerning the states of matter . It is commonly estimated that in our and other solar systems, 99.9% of the matter is in the form of plasma , whereas less than 0.1% is in gaseous, liquid , or solid form. Plasma seems to be the overwhelmingly dominant form of matter, perhaps reflecting how stars achieve thermonuclear ignition by having a mass much greater than that of dark bodies.

Plasma is commonly characterized as gas that has undergone ionization. Ionization involves matter that contains electrically charged factors, that is polar particles or force fields that repel like and attract unlike counterparts with electro-magnetic force. When gas is ionized some of its electrically charged particles are stripped off, leaving the gas with a charge, even if the sum total of positive and negative charges remains equal. Through ionization these opposing charges no longer remain cohabiting a gas ; instead, some have been separated off. In this empirical account, plasma , as a form of matter, evidently depends upon polar electromagnetic charges.

Aristotle will distinguish the elements, by contrast, without invoking the specific polarity of electric charge. He will, however, invoke other physical contraries to distinguish the elements

and comprehend how they get transformed into one another. Aristotle ’s account is important to consider in seeing how the philosophy of nature can advance between conceiving locomotion to address qualitative physical transformations.

8.2 The Lessons of Aristotle ’s Account of the Elements

Let us first examine Aristotle ’s account of the elements in respect to the basic challenge of a qualitative physics, transcending the limits of pure mechanics . Two rudimentary challenges must be met if there is to be any way of advancing the philosophy of Nature beyond matter in motion and how bodies get distinguished from one another by how they move. On the one hand, there must be a physical process involving something other than material locomotion , such as light provides. On the other hand, physical process must provide for a differentiation of matter that goes beyond the distinctions provided by inertial and gravitational interaction. The light process has involved a rudimentary distinction between self-illuminating emitters of light and lit bodies, to which Hegel has added the astronomical physical differentiation of stars, moons and comets, and planets. These physical differentiations draw upon the effects of gravity , which Kant and Hegel may regard to be endemic to matter, but which Aristotle rejects by connecting place to types of physical substance.

There are different kinds of self-illumination that are found to occur in Nature . First and foremost, there are stars—the self-illuminating bodies that center solar systems, possessing the preponderant mass whose gravitational compression can ignite thermonuclear fusion. Their self-illumination is grounded upon the degree to which their own matter’s gravitational field compresses them to the point of light emission. This process is described as involving nuclear fusion. What kind of relationships are at play in such fusion? We are not dealing with chemistry, where molecular structure gets altered. We are instead dealing with nuclear physics, where atoms themselves get transformed, either through fission or fusion, that is, through the breaking apart or combining of atomic nuclei. Fusion might be thought to apply to matter in general if matter involves certain basic material constituents, differentiated in terms of not just mass and motion, but physical differences of electric charge and spin. Although the most rudimentary atom might be identified empirically as hydrogen, nuclear structure in general can be thought to involve basic physical factors that are found in hydrogen and every other element. Fusion involves these factors and nothing more need be invoked for its operation.

This may be entailed by the basic relations of light. What would be the next physical differentiation and what would be its enabling conditions? Might the fundamental elements, that is, the qualitative states or phases of matter, be the answer? Both Aristotle and Hegel follow this lead and turn to develop the elements of so-called air, fire, water, and earth, elements whose transformation into one another renders them ultimately equivalent to the states of matter , gas , plasma , liquid , and solid . Both further connect these elements to astronomical relationships, distributing the elements to different bodies.

How are these elements distinguished? Can they be differentiated without introducing any further physical differences that have not yet been established? If so, in what respect are they primary physical differentiations, and in what way do they add something irreducible to what went before? Can the polar differentiation of electric charge suffice to provide what is needed for there to be distinct states or phases of matter? Could this already be delivered by the light process, if light is electromagnetic in character? The binary difference of positive and negative charge seems to be the most basic physical distinction that could supervene upon the mechanical differences of bodies and that between self-illuminating and lit matter. Aristotle , however, will employ two sets of different contraries to distinguish his elements, the contraries of wet and dry and of hot and cold. Do these contraries rest upon more rudimentary physical differences or can

they play the role of defining the basic elements, or states of matter, on which all further physical reality proceeds?

Aristotle determines the basic physical elements not so much in the *Physics*, as in two much briefer works, *On the Heavens* and *On Generation and Corruption*. Both of these works do rest upon the *Physics*, which concerns the most basic determinations of nature . Admittedly, the discussion of the *Physics* is not at all mechanistic, since Aristotle offers no laws of matter per se nor reduces natural process to the external necessitation of efficient causality in indifference to the essence of things. Nonetheless, the *Physics* is largely focused upon motion in the broadest sense, with recognition of the primary role of locomotion is setting all other motions in play.

The differentiation of elements comes up, significantly, in connection with consideration of the heavens, of a certain kind of natural substance with a distinctive location and type of motion (e.g. circular) that differs from that of terrestrial things. The process of the elements is then further developed in regard to generation and corruption, which proceeds on the basis of the physical reality of the heavens and the earth. Aristotle is not afraid to raise the question of whether there is more than one element, or whether everything is reducible to one omnipresent factor.

What is an element for Aristotle ? An element is not equivalent to substance in general, which sometimes is thought of as a basic composite, combining form and matter. Plato tends to speak of substance as such a composite relation of form and matter. Aristotle , by contrast, invokes the relation of form and matter with regard to artifacts, which can be conceived to be composite precisely insofar as they are produced by an artisan imposing form upon some given material. Things get more complex when the form in question is a soul, as Foster characterizes the active form with which Aristotle characterizes what is a substance by nature . Such a form has a very specific relation to its matter. However substance in general be conceived, an element is distinct from substance itself insofar as an element is in any way a particular type or state of physical being. The elements are rather either particular kinds of natural substances or a particular state of natural substance, which can be transformed into the other states or elements.

Can Aristotle coherently consider the elements to be different types of matter? Matter, for Aristotle , is itself indeterminate and devoid of any laws of its own. Matter is formless, it is pure potential, and only obtains a determinate actuality when it is a component of a substance with a determinate form. Matter in and of itself can hardly have any types, nor for that matter, any states or phases.

The elements, therefore, are not just matter, nor just substance in general. Insofar as the elements can each arise out of one another, they have an independent existence, rather than just being the component of something more concretely determined. There might be different types of earth, water, air, and fire, and physical substances might contain more than one element. Nonetheless, because the elements can exist apart, they must be a type or state of substance, containing both form and matter.

If, however, the elements contain matter, as well as form, they will be in a position to incur both further form determinations as well as accidental attributes and relations. Each element might then be susceptible of taking on a range of different kinds of qualifications. Do the elements then undergo alteration or do they become something else? To alter, without ceasing to be, an element takes on new attributes, while retaining its defining form. In that case, the element changes in a certain respect while retaining its specific nature . Like substance in general, the element then figures as a substrate of change. Matter, by contrast, cannot change for it has neither any determinate attributes nor any independent determinate being that can persist. When

matter takes on new form, matter itself does not undergo a change. Rather, a determinate substance comes into being or ceases to be. When matter becomes associated with a new attribute, it is not matter that changes, but the substance that contains that matter.

Aristotle does think of elements as being basic types of physical entities. On the other hand, he conceives them from the very beginning to be determined in terms of the *process* that they undergo. This process is not alteration, but rather a process of "generation " or "corruption", of coming to be and ceasing to be. Insofar as the element are the fundamental forms of perceptible, tangible reality, and they are subject to the process of becoming, the conception of the elements is equally a conception of the inexorable becoming to which physical nature is subject.

What is the process of becoming to which the elements are inherently prey? Significantly, the becoming and ceasing to be of the elements is a process of their transformation into one another. If it were not, as Aristotle recognizes, nature would lose both its physical entities and the process of becoming distinguishing physical nature from the eternal being of the divine.

The key point in Aristotle 's conception of the elements is how and why they transform into and out of one another. What is it about physical reality that causes the basic forms of physical reality, the elements, to undergo transmutations into one another? The answer to this question, not surprisingly, resides in how the elements are differentiated in the first place .

In Chap. 5 of Book III of *On the Heavens*, Aristotle clears the ground for his differentiation of the elements by critiquing the opposing views of his predecessors. He points out that the pre-Socratics generally conceived reality to be composed ultimately of one element, which they variously characterized. They all thereby faced the problem of accounting for the entire differentiation of physical reality in terms of one privileged factor. [2] The difficulty of doing so provides a guiding thread to the discussion of the basic elements, whose diversity can better cope with the task of determining nature in its concrete fecundity.

Although the elements may be the primary types of physical entities, they are not equivalent to individual objects, which have a specific nature of their own above and beyond what element or elements they may contain Just as the pre-Socrates confronted the challenge of determining how different physical entities could be composed of the same single element, so Aristotle faces the challenge of determining how the four elements he identifies provide the enabling conditions for the differentiation of individual things with specific natures of their own.

As Aristotle points out in his critique of the pre-Socratics, appeal to a single element leaves one with no qualitative differentiations to rely upon in accounting for the cornucopia of nature . All one can bring in are quantitative relations, such as the amount and spatio-temporal geometric distribution of the one and only element. One can invoke the density or rarity of this element and try to differentiate everything in terms of such distinction, as the atomists attempted in appealing to the arrangement of identical atoms in the void . [3]

So long, however, as quantitative differences are all that are available, the question arises how difference in quantity, which is continuous, gives rise to nodal points where quantity turns into measure, that is, into a quantitative determination that equally constitutes a qualitative difference. Where and how does one draw the line where quantity turns into quality, to paraphrase that old Diamat Marxist bromide? It seems that any particular point on a quantitative continuum would be an arbitrary place to distinguish something from something else. One may say that something is less dense than something else, but how does that give it a different specific nature , and what qualitative features come into being at that quantitative juncture? Without introducing some other resource we seem to be at a loss to establish when a quantitative difference becomes a qualitative distinction.

A similar problem arises when you have not a single element, but a single principle of *construction*. Aristotle points to the difficulty facing those of his predecessors who want to construct physical reality out of geometric planes. [4] They seek to generate kinds of natural things by the geometric shape they have. Can shape , however, be equivalent to every distinguishing feature of a natural entity?

A fractal arrangement might seem to resolve this problem. In a fractal pattern, every part of the shape is identical to the whole. In other words, the fractal pattern exhaustively determines every detail of the entity to which it belongs. How can this geometrically thoroughgoing determination have a physical realization? A physical entity occupies a place . If we are going to distinguish natural substances just by their shapes, we will have to conceive them as composed of homogeneous factors, such as identical particles or atoms, whose arrangements make all the difference. Yet, as Aristotle points out, anything that occupies a place can be divided in various ways. What is thereby defined by a certain shape loses its character the moment it is ascribed a different division. Geometry itself offers no grounds for privileging one division over any other. If, however, shape is the basis of all physical diversity, that diversity loses all reality. Moreover, geometric shapes, and especially those constructed from planes, cannot fill up every volume in nature , given the irregularities of surfaces and contours in nature . Nor can they account for irregularities in the internal composition of natural substances.

Moreover, and perhaps most importantly, nature involves different processes with different kinds of motions, of change. Geometric construction provides no dynamic principle that can account for things with shape undergoing any change, nor account for how they have come to have the shape they possess, as well as the place they occupy. Just as one element provides nothing sufficient to produce a plurality of natural processes, so one principle of construction is at a loss to establish the different motions to which nature is subject.

Looming large is the further question regarding generation and destruction. Terrestrial natural substances may appear to come to be and cease to be, but can the elements out of which they are composed be eternal? Or are the elements necessarily going to be subject to generation and destruction? This question must be tackled if the elements are to be transmutable into one another, which would render them more like physical states of matter than physical elements . If they continually transform themselves into one another, then they seem to be generated and destroyed, and cannot be eternal. If the process of transformation continues without end, however, they seem to be continually replenished and nature always contains them.

Why can the elements not be eternal, precluding their generation or destruction?

In addressing this question, Aristotle notes that all the would-be candidates for elements involves analysis and synthesis. Insofar as all things of nature are composed of the elements, these things can be analyzed into their constituent elements, just as all things are constituted by the synthesis or combination of elements. In this way, the elements provide for the diversification of natural entities over and beyond the difference of the elements from one another. How do these complementary “processes” of analysis and synthesis bear upon whether the elements are eternal or not? To the extent that these processes go one indefinitely, nature contains an indefinitely infinite development involving the aggregation of elements in synthesis and their separation in analysis. If these processes came to an end, so would all change, as well as all generation and corruption.

If, then, the elements are generated, what are they generated from? Can they be generated from something incorporeal? There would seem to be two incorporeal factors to which Aristotle can appeal: the unmoved mover and the void . Can the elements be generated from either?

Since the unmoved mover only thinks its own unchanging thought of itself, it is even harder to see how it could generate the elements than generate the eternal circular motion of heavenly bodies. To generate an element that does not already exist would require some change in the unmoved mover, which goes against its unchanging, unmoved nature . The unmoved mover is not a creator, nor a demiurge who imposes form upon chaos.

Can the void generate anything? Can something come from nothing? Hegel may have shown how matter can only be constituted from immaterial factors, and how space, time , and place provide enabling conditions for extension. His argument, however, does not directly engender determinate elements, or phases of matter, but just matter per se.

At times, Aristotle calls into question the very existence of a void . [5] Everything that is is substance or relations of substances. Although the unmoved mover is an immaterial substance with pure actuality, all other substances are material and occupy some place . Accordingly, everything that is in nature is material substance or relations of material substance. There can be no void , if the void is devoid of any relation to substance. In his popularization of the theory of special and general relativity , Einstein suggests, in an analogous vein, that space should not be thought of as some empty receptacle in which bodies may move, but rather as something that is an aspect of bodies and the relations of their inertial frames of motion. [6]

One might think that Aristotle ’s distinction between place and a particular body allows for place being occupied by a void , by empty space. This does not automatically follow, however. Place can retain its distinction from a particular body without establishing empty space insofar as a different body can enter and occupy a place whenever a natural substance moves to another location. Locomotion will thus involve a continual replacement of one body ’s occupation of a place by another body .

If the element cannot be generated from anything incorporeal can they be generated from any other corporeal factor? There is a simple reason why this cannot be possible. If the elements are the fundamental constituents of all physical substances, then there can be nothing material that is not composed of them. Hence, nothing material distinct from the elements can possibly generate them. If some material factor were what generated them, that material factor would itself be an element. Hence, there is only one alternative left: the elements must be generated from one another.

We are left with the following result: the elements are not eternal, but are generated from one another. Does this outcome cohere with what Aristotle has had to say about bodies in general. In particular, can it be compatible with Aristotle ’s claims concerning the eternal heavenly bodies.

These bodies had to be eternal because motion must be eternal. Any generation of motion is itself a change, creating an infinite regress reinstating the eternality of motion. Since motion is a change of a substance and continuous circular motion can be unchanging, there must be material substances occupying place that can move forever in a circle. These eternal heavenly bodies are the only possible recipients of motion from the unmoved mover, which can only impart an unchanging eternal motion.

Does this mean that the eternal heavenly bodies are composed of an element that is eternal. Or is the element of which these bodies are composed subject to transmutations even though these entities retain their character owing to the specific circumstances of their movement? What do we know about them? First of all, the celestial bodies move eternally in a regular circular motion elicited by the unmoved mover. Second, one must take into account the implications of what Aristotle has to say about light in *De Anima* on light. [7] There Aristotle maintains that the stars have something fire-like about them, which enables them to emit light in an unceasing

manner. They are a party to the process whereby visibility is realized. This allegedly requires a medium engaged in the activity of being transparent. Fire is connected with the activation of the transparent medium through which light illuminates. This suggests that the celestial objects have the element of fire.

Is the fire of the self-illuminating celestial bodies eternal? Is it generated? Does it get transformed into any other element? What are the options we might have before us? Even if the celestial objects have to move eternally, do they have to shine forever? Could the fire of a star exhaust itself and become extinguished without altering the eternal circuit of its locomotion ? And if a star ceases to shine, has its fire transformed itself into another element, and if so, which one or ones? If the fire of the star consumes itself without transforming into another element, would the star cease to be, forsaking its eternal existence? Alternately, would not a transformation into water or earth give the celestial body an element whose natural place is terrestrial, interfering with its eternal motion?

To clarify these questions, we need to consider how and why Aristotle conceives the elements in connection with the thesis that they transform themselves into one another. We have pointed to problems that suggest that the elements cannot be generated from something incorporeal and that they cannot be generated from something that is not an element. So they're generated out of another element. This proviso does not yet tell us whether every element gets directly transmuted into every other one. So far, all that follows is that each element arises from at least one of the other elements. Matters get further complicated once we take into account that the elements are not eternal. The element out of which an other element arises would itself have to arise from some other element.

In chapter seven of Book III of *On the Heavens,* Aristotle points out that this process of element generation should not be thought of as involving an excretion, where we have some element to start with and then the other elements emerge from it as if they were there within it already. [8] Such an account fails to explain how any element comes into being, for it presupposes that all are present from the start and the "generation " is merely a matter of preexisting things getting separated out.

Even if we were to grant that the generation of the elements consists in a separating out of these factors, we face the problem that the whole process would have to come to an end. A process of excretion cannot go on forever. To do so, the physical substance from which elements are generated would have to contain an infinite amount of material, but what occupies a determinate place is finite. Since its substance has a limit, at some point its "excretion" must exhaust itself, eliminating all further "generation ". If, however, the elements are not eternal, nature will disappear unless generation can continue indefinitely.

The persisting reality of nature requires that the transformation of elements into one another must go on without end. Their generation and corruption must continue. It is on this basis of their continual transformation into one another that the elements must be conceived.

To comprehend the process of generation and corruption, we must comprehend how one element can cease to be by turning into another element that thereby comes to be. In Book II Chap. 1 of *On Generation and Corruption* [9] Aristotle identifies what he understands the elements to be, doing so in terms of their coming to be and passing away. The elements are, he maintains, the primary materials whose change results in coming to be and passing away rather than mere change of a persisting material substance. The elements are the principles of coming to be and passing away. They must be distinguished from the matter of perceptible bodies because the elements all contain matter in a specific qualitative state. Matter, as Aristotle points out, has no

separate existence, but only exists when it is bound up with a contrariety. Ordinarily, a contrariety is a determination of a substance that cannot exist together with its contrary. A persisting substance undergoes change insofar as one of its contrarieties is replaced by its contrary.

Matter, as indeterminate, has no intrinsic connection to any contrariety or any other qualification. The elements, however, are characterized by Aristotle , as having an intrinsic connection to a pair of contrarieties, namely wet and dry, and hot and cold. The identity of each element is tied to its possessing one of each pair of these contrarieties. Fire is dry and hot, water is wet and cold, air is wet and hot, and earth is dry and cold.

Consequently, when an element has one or both of its contrarieties replaced by their respective contraries, it turns into a different element.

Whereas matter in general has an indefinite potential, which can be actualized in the embodiment of any materializable form, the elements have a more determinate potential, since each intrinsically possesses two of the wet/dry and hot/cold contrarieties. On the one hand, each element can take on whatever qualities are compatible with and therefore not contrary to its defining contrarieties. On the other hand, each element is susceptible of passing away into another element in function of whether just one or both of its contrarieties is replaced by its respective contrary. Fire (hot and dry) gets transformed into air (hot and wet) when its dryness gives way to moisture. Fire gets transformed into earth (cold and dry) when its heat gives way to cold. Fire gets transformed into water (cold and wet) when both its defining properties are replaced by their contrarieties. Similarly air becomes fire or water when one of its contrarieties is replaced, and becomes earth when both contrarieties give way to their opposites, whereas water becomes air or earth when one of its contrarieties is replaced, and becomes fire when both give way to their opposites. By the same token, earth is transformed into water and fire when one of its contrarieties is replaced, and becomes air when both of its contrarieties give way to their opposites.

We have here a threefold level of specification of physical reality. Matter in general, as pure potential, exists with some form that is other to what it is not. The matter of nature is potentially a perceptible body , a “this” of a kind with a sensible, rather than merely intelligible reality. Then we have the contrarieties that matter can take on so as to be perceptible, so as to be tangible, so as to be physical. Aristotle gives as an example, heat and cold. [10] Thirdly, we have the elements, which change into one another. The contrarieties do not themselves change, but remain what they are. Whether a physical body possesses them, however, is subject to change. Whether an element possesses them is a matter of its generation or corruption.

The physical contrarieties are such as to be the opposing determinations that a natural substance must possess to be perceptible, to be something physical, something tangible. Their presence is constitutive of the actuality of the different elements. It is also the key to why the elements get transformed into one another.

Do any physical entities change into one another besides the elements? Natural substances may change, but does anything other than an element come to be or cease to be? Do the transformations of the elements contained by substances render them subject to becoming and not just change?

Let us grant, following Aristotle , that physical bodies that change into one another are going to involve an elemental change and that anything else will just be alteration. How then must the elements, the primary bodies, be differentiated? Aristotle tells us: they are going to be differentiated in terms of the contrarieties of tangible qualities. Only *tangible* qualities can

distinguish elements. Neither whiteness nor blackness nor sweetness nor bitterness nor any of the other non-tangible perceptible contrarieties constitute an element. Why is that? Are not contraries given to vision, hearing, taste , and smell just as physically real as tangible contraries that are available to touch? They may indeed be physical real, but what here lies at stake are the physical contraries in and through which the elements get transformed into one another. We have to ask, why are tangible contraries solely relevant? And how many tangible contraries are going to count as principles of the different elements?

We are looking for principles of perceptible, tangible bodies. Aristotle admits that there are other perceptible qualities besides those that differentiate the elements. In *De Anima*, however, Aristotle claims that touch is fundamental, underlying all the other senses. [11] Not only can we not have our other sense organs without possessing touch, but if one descends phylogenetically down the ladder of animal life forms, one finds animals that are blind but one can never find any animal that does not have a sense of touch.

What makes something visible, allows it to sound , and gives it smell and a taste are all, Aristotle would certainly agree, physical processes. Although being visible operates at a distance thanks to the intercession of some transparent medium, visibility, he acknowledges, is a quality of a tangible body . [12] The guiding thread is that elements are differentiated in respect to tangible properties.

Aristotle begins by listing tangible contrarieties: hot and cold, dry and moist, heavy and light, hard and soft, viscous and brittle, rough and smooth, course and fine. He then eliminates the heavy and the light because they are neither active nor susceptible to action. [13] That is, things are not heavy and light because they act upon something else or because they suffer action from other things. They maintain their character as heavy or light independently of such interaction.

Why is an intrinsic connection to action or suffering action a criterion for ruling out tangible contrarieties as bases for distinguishing the elements? Tangible properties that lack such connection are not going to enable an element to transform itself into another element.

The reason why Aristotle excludes non-tangible perceptible properties from differentiating the elements can be seen to reside in the same deficit. They, too, are unrelated to the efficacy or susceptibility to influence of the substance to which they belong. This is related to how the non-tangible properties do involve immediate contact with other physical substances. They can be perceived at a distance, or, at least in the cases of odor and taste , without completely altering all of what is smelled and tasted.

Elemental distinctions are those that bear upon a type of physical being that gets transmuted into another kind of physical being in function of its defining contrarieties. Elements are differentiated by factors that allow each element to both be distinguished from its counterparts and to be transformed into them. Owing to their endemic transmutability the elements are both active and susceptible to action. As such, they interact and transform into one another.

This leads Aristotle to focus on two pairs of tangible contrarieties as being exclusively determinative of the elements: hot and cold on the one hand, and dry and moist on the other. These occupy a privileged place because they involve the power to act and a susceptibility to transformation.

Heat associates things of the same kind by dissociating different things, expunging what is foreign and leaving behind only what is similar. That is the kind of activity heat possesses. Cold, by contrast, brings together what is homogeneous and heterogeneous alike. Cold holds both in place , as exhibited in freezing.

The tangible contrarieties of moist and dry have a different efficacy. What is moist is readily

adaptable in shape and it does not have any determinable limit of its own. In other words, it is liquid , flowing to fill whatever vessel may enclose it. What is dry, by contrast, has its own determinate limit and is not readily adaptable in shape . Lacking the liquidity of the moist, the dry retains the boundary of its solid , relatively rigid configuration. The dry could be said to be "readily determinable by its own limit" through the process of drying, where something solidifies and thereby takes on its physical limit as a solid . [14]

The elements and the process of their transformations into one another, the process of their generation and corruption, is now to be developed in terms of these two sets of contrarieties—hot and cold, and moist and dry. The contrarieties of fine and course, viscous and brittle, hard and soft are left behind. That they do not distinguish the elements is easily seen by how earth can be hard or soft or brittle or fine or course, just as water can be viscous and, depending upon its relative motion to an impacting body , hard or soft.

The decisive point, however, is that, as Aristotle indicates, these other physical contrarieties are all derivable from hot and cold and moist and dry. [15] The fine derives from the moist since the fine can adapt to any shape . Sand, for example, can fill up any container, and do so more easily the finer its particles are. The viscous is also connected to the moist. What is viscous is something moist that has been thickened. Similarly the brittle is a form of the dry, which is so inelastic that it easily fractures under any pressure. The soft derives from the moist since the adaptability of the moist allows something to be soft, that is, to meld itself around, rather than rigidly resist any intrusion.

Consequently, we are left with hot and cold as well as moist and dry as the basic, non-derivative tangible contrarieties by which the elements are determined. They cannot be reduced to one another, for the hot is not essentially moist or dry, any more than the cold is essentially moist or dry, or the moist is essentially hot or cold, or the dry is essentially hot or cold. Although each contrariety cannot coexist with its own counterpart, each can be associated with either of the other contrarieties.

Aristotle generates four elements out of these two pairs of contrarieties. Why are there only four? As Aristotle himself admits, four terms can be coupled in six, not just four ways. Two of the abstractly possible couplings are not actually possible, however, because opposites cannot be coupled. Hot and cold cannot coexist any more than can moist and dry. As a result, only four couplings are realizable: hot and moist, hot and dry, cold and moist, and cold and dry. [16]

Significantly, Aristotle maintains that we have to have couplings. The elements cannot just be hot or cold, or moist and dry. At one point, towards the end of Book II, Chap. 3 of *On Generation and Corruption*, [17] Aristotle does indicate that one can identify each element primarily with one of the two tangible contrarieties that distinguish it. Earth can be characterized by being dry, leaving out the cold, just as water can be characterized by cold, leaving out the moist. Similarly, we can characterize air by being moist, leaving out being hot, and fire can be characterized by being hot, leaving out being dry. Generally, however, Aristotle will have fire being both hot and dry, air being both hot and moist, water being cold and moist, and earth being cold and dry. Only when both defining contrarieties are considered can the process of the elements be understood.

The primary reason why both contrarieties are essential is that otherwise there can be no transformation of one element into another. The process of transformation depends upon the elements sharing at last one factor. Otherwise there is no link between them to account for how one element's demise leads to any specific other.

Elements that do not share any contrarieties are in no position to get directly transformed into

one another. Water and fire do not share any contrarieties since water is cold and moist, whereas fire is hot and dry. Similarly air and earth have nothing in common, since air is hot and moist, whereas earth is cold and dry. In order for water and fire or air and earth to become transformed into one another, both of their respective features must be altered. For fire to turn into water, the hot must give way to the cold while the dry must give way to the moist. Similarly, for air to become earth, the moist must give way to the dry and the hot must give way to the cold.

The presence of two pairs of contrarieties allows for two different types of processes, one involving an alteration of only one contrariety and another requiring an alteration of both contrarieties. Unless both contrarieties can be transformed at the same time , the process where both contrarieties alter will actually consist of two successive processes where one contrariety is altered, such that, for example, air becomes earth by first becoming water.

One more significant feature enters into the process of the elements in Aristotle ’s account, which is discussed in Book II, Chapter three of *On Generation and Corruption*. There Aristotle points out that, given how physical bodies are distinguished into those that are celestial and those that are terrestrial, the elements will fall into pairs that belong to these different regions. The elements will belong to different regions. Fire and air are forms of physical reality that move towards the limits, towards the heavens. By contrast, earth and water are forms of physical reality that move towards the center, towards what is terrestrial. [18]

Does this mean that there is and can be no fire and air on the ground? Or, alternately, no earth and water in the heavens? Aristotle himself has noted how natural substances may not be in their natural location because of countervailing circumstances. Accordingly, although fire and air by nature may ascend, they can be kept down by external forces, just as earth and water might not fall owing to opposing causes.

Indeed, the very process of the elements suggests that the two celestial elements, fire and air, cannot be kept irrevocably apart from the two terrestrial elements, earth and water. Precisely because the elements change into one another, wherever they may be, they will be subject to a continual movement to and from the regions to which they belong by nature . If earth or water change into either fire or air, they will drift towards the heavens, unless something else impedes their ascent. Alternately, if fire or air change into earth or water, they will fall to the ground, unless countervailing factors intrude. If the process of element transformation is continuous, as Aristotle has argued, then there will be a continual cycling of the elements from one region to the other, precluding any ultimate separation and ultimate extinguishing of their generation and corruption. The elements may be primed to engage in this continual cycling, but what actually *causes* the changes in the contrarieties on which their identities depend? The elements, by nature , have been identified with regard to place and with regard to a distinctive pair of tangible contrarieties. By nature , they are not eternal, but transmute themselves into one another. Nonetheless, what makes them transmute themselves at any specific time and place ? What provides a basis for each transformation? What, for example, causes the celestial bodies to change, at least in part, from fire into air or water or earth? Moreover, is there any pre-stabilized harmony governing the transformations, such that every element remains in relatively equal supply? Or could everything end up being transformed into fire, which then all turns into one of the other elements? If the transformations all coalesced into the generation of one and only one element, how could there be both heavens and terrestrial spheres. And if there were no heavens, how could the unmoved mover continue to generate eternal motion, on which all change depends? Without the fire of the heavens, everything else would stop moving and the process of nature would be annihilated.

The process of element transformation must therefore ensure an ongoing cycling of all the elements, so that heavenly and terrestrial regions persist in their symbiotic relation. What, however, can account for the proper continuation of all of this?

However this problem be addressed, it should by now be evident that Aristotle ’s account of the elements entails a basic ambiguity concerning the identity of these fundamental types of physical substance. Are the elements particular types of matter or are they states of matter that individual materials take on as a particular phase of their physical metamorphosis? Is water a particular physical substance containing oxygen and hydrogen, distinguished from other physical substances like alcohol or mercury or liquid helium? Or is water the liquid state of matter that all these different tangible substances occupy under certain physical conditions? Is the element “water” really the liquid state of physical substance, opposed to the solid , gaseous, and plasma states, which all types of matter pass through, transforming themselves from one to the other, without forfeiting their own particular nature ?

We might consider all these phase changes of physical substance to be dependent upon temperature, where something is in a solid , liquid , gaseous, or plasma state owing to the degree of heat and cold it possesses. In this case, it might appear that the physical state of a physical substance depends on one of the contrarieties invoked by Aristotle : hot and cold. Whether something is moist or dry would seem to be derivative upon the heat it possesses and how that heat leaves it liquid or not. What is liquid , and in some respect, moist, will, if heated sufficiently, turn into air, that is take the form of a gas . If sufficiently cooled, what is liquid and moist will solidify. Although at what degree of heat these transformations occur may be contingent upon the particular other qualities a material has, *all* material could be said to pass through these phases or states. They are simply generic to physical matter and for that reason they are fundamental aspects of physical reality that precede in reality and conception an account of what further distinguishes physical substances from one another.

Once we recognize the elements to be fundamental physical states of material substance, we can rethink the process of their transformation into one another. The contrariety of hot and cold will play a fundamental role. Pressure may also be invoked to the extent that it impacts upon the energy heat must have. The contrariety of moist and dry will be secondary to the extent that the moist depends upon the liquid state, which has specific temperature (and pressure) conditions. Moreover, the regionality of the elements can be reconceived in terms of how the states of matter impact upon physical density and the gravitational interaction of physical materials. Gas and plasma will rise above more dense liquids and solids when all are subject to the gravitational attraction of some central body .

The passage of one state of matter into another will then typically depend upon changes in temperature and pressure, which themselves may be tied to the self-illuminating nuclear “fire” of stars and the gravitational mechanics of solar systems.

8.3 Kant and the Physical States of Matter

In the “General Remarks to Dynamics”, [19] Kant discusses some physical features that bear upon the differentiation of the elements, particularly as reinterpreted as phases of material substance. At the very beginning of those remarks, Kant addresses differences in density , which Kant had earlier pointed out is made intelligible in virtue of the dynamic conception of matter. [20] By conceiving matter to consist in a combination of attractive and repulsive moving forces, one escapes the trap of atomism, which makes the mistake of postulating impenetrable particles surrounded by empty space. Atomism must then conceive differences of density to consist in how much empty space intervenes between its atoms and how many of these particles fall within a particular body of a certain volume. The dynamic constitution of matter allows for differences of density without having to admit either impenetrable atoms or empty space. [21]

How, then, are differences of density constituted? It might seem that something is more dense than something else because it contains more repulsive force in the same volume. Kant has pointed out that the repulsive force on the surface of a body becomes more concentrated as that body is compressed, suggesting that such a body , while retaining the same mass , becomes more dense in line with the concentration of its repulsive force in relation to the diminished volume that body occupies. Although the total repulsive force of the body may remain the same, it is contained within a decreased volume, which makes it more and more difficult to compress the body as it becomes more compacted.

This reference to the compression of a body would hold between different material substances if their material were homogeneous. How do we identify material homogeneity? What resource do we have for that? If there is such a resource, it suggests that there can be heterogeneous materials. In that case, Kant claims, we cannot compare their density in terms of their repulsive force because it is not clear that every type of matter has the same amount of repulsive force in relation to its attractive force. [22] Again, however, one must ask on what basis can types of matter be heterogeneous? What would allow for and cause such heterogeneity? The dynamic conception of matter offers nothing more than the countervailing attraction and repulsion that is common to all material bodies. Quantitative differences might be had, but can these entail qualitative differences, let alone differences of material intensity?

One can see that these questions may well bear upon the possibility of distinguishing states of matter . So, too, may the question of whether there is empty space. The dynamic conception of matter may, as Kant suggests, allow material extension and differences in density to be without invoking atoms and the void , but this does not of itself preclude empty space. Kant notes that the dynamic conception of matter at least deprives empty space of any necessity, [23] but its possibility is not ruled out. Even if a body may contain no empty space within itself, can there not be empty space between different bodies? Does gravity not attract at a distance, crossing unoccupied stretches of the cosmos?

Moreover, could the dynamic conception of matter allow for “particles” composed of force fields of attraction and repulsion to be constituents of atomic structures separated by empty space once electromagnetic polarity supervenes upon matter? Could not there then be negative and positive particles forming atomic and molecular structures, where nuclei are separated by empty space from electrons and atoms interlace through electric charges that disseminate through intervening space?

In considering these questions, it is worth taking note of what Kant has to say about the limits

of his metaphysical investigation of the foundations of natural science. This investigation does allow us to get rid of principles that have not yet been properly criticized, such as the principle that matter is composed of impenetrable atoms in empty space. In this respect, Kant's metaphysical investigation of the foundations of natural science has a negative character, protecting us from accepting insupportable concepts of nature . Positively speaking, Kant's account restricts itself to developing the principles that make matter as such possible—the dynamic conception of matter determined by repulsion and attraction, and the further basic principles of mechanics that govern bodies in motion. Kant admits that he cannot provide a sufficient explanation of the possibility of the specific variety of physical substances, but in his "General Remark to Dynamics" he announces that he will attempt to present the basic determinations by which matter's essential differentiation can be understood. [24]

Kant might seem to be embarking on an exploration parallel to Aristotle 's investigation of the elements, attempting to uncover the fundamental types from which all the variety of natural substances are composed. Kant, however, can not employ the various distinctions between celestial and terrestrial bodies and between physical contrarieties on which Aristotle relies. Instead, Kant must draw upon the comparatively meager resources that his pure dynamics and mechanics of matter in motion provide.

Kant has introduced differences in density , based on the dynamic forces inherent in matter and later in his "General Remark to Dynamics" he presents another physical relationship with respect to which bodies can differ: cohesion . Cohesion might seem to be the complement of density since cohesion appears to depend on how much attractive force keeps the parts of bodies together, whereas density , on Kant's account, concerns how much repulsive force a given volume of matter contains. Kant points out, however, that cohesion is not reducible to the basic force of attraction constitutive of matter. He, instead, identifies cohesion as something derivative. What exactly is cohesion and why is it derivative, rather than basic?

Cohesion differs from the fundamental attractive force of matter because it concerns how the *surfaces* of different parts of a body or of different bodies adhere to one another. The basic attractive force, like gravity , acts not just on the surface of bodies, but throughout their extension as well as at a distance. By contrast, cohesion involves a force of adhesion that operates merely through the contact of the surfaces of touching bodies. As such, it presupposes the physical presence of those bodies, which depends upon their own attractive and repulsive forces. Admittedly, Kant has tended to distinguish attraction and repulsion by treating attraction as a penetrative force, while describing repulsion as a surface force, which accordingly is more immediately tangible and more immediately given to our sense of touch. Nonetheless, repulsion cannot account for the extension of matter unless it operates throughout the body it helps constitute. If it only operates at the surface, the interior collapses, leaving an empty, infinitesimally thin shell. Kant does acknowledge that experiments indicate that cohesive force is active at a very small distance. If sufficiently close, a piece of paper will be drawn to a surface to which it then adheres. Is this a phenomenon of cohesion or something depending upon static electricity ? Or is cohesion something that can only be explained by bringing in the additional polar forces of negative and positive charges?

Kant brushes aside the indication that cohesive force might operate at a distance when the separation of the bodies in question is very small. [25] Cohesion is neither just the attractive force constitutive of matter, nor an example of gravitational attraction. It is something else. Since we find it operating only across the tiniest divides, for all practical purposes, it should be considered a force that operates through surface contact. Cohesion is a superficial force, not a penetrating

force.

Kant, however, adds that cohesion only possesses full strength when the bodies in question have passed from a prior state of fluidity to one of solidification. Then the bodies will adhere to one another with maximum cohesion . [26] The role of this phase change from liquid to solid indicates that cohesion is not just a matter of attraction, but involves a discrete physical process. Kant points to this by contrasting the bond that is achieved when the parts of cracked mirror are fitted back together to that resulting from melting those parts and then pouring them into a mold in which they can solidify into a fully cohesive piece of glass. It may not be easy to separate two uniformly flat pieces of glass that are placed on top of one another, but they still can be slid apart with sufficient force, unlike pieces that have been liquefied and subsequently solidified. Kant concludes that the force of cohesion cannot be a fundamental force of matter in general, but only a derivative force. [27] It is not enough to simply change the position of bodies to get them to cohere. Something more must be added. There must be a change in the *state* of matter, namely, a change from a fluid to a solid state.

Through cohesion , Kant now confronts the challenge of conceiving the physical distinction between fluids and solids. The context is one in which these come into play not as separate elements, but as different states of matter that change into one another. Solids are to be liquefied and liquids are to be solidified for full cohesion to be achieved.

Does this mean that Kant can distinguish liquid from solid in terms of differences in cohesion ? A fluid, as Aristotle acknowledged in characterizing the element of water, changes its shape to adapt to its container, whereas a solid is relatively rigid. Does this difference make a liquid less cohesive than a solid ? Does the flowing character of a liquid mean that its parts can be drawn apart more easily than those of a solid ? Certainly, one can separate parts of a glass of water more easily than one can separate the parts of an iron bar. Is, however, the distinguishing difference between liquid and solid a matter of differing cohesiveness? Full cohesion might arise through solidification, but does this mean that the difference between a solid and liquid is just a matter of degrees of cohesiveness?

Kant maintains that degrees of cohesiveness is not what distinguishes solids from liquids. Something else is involved. To understand what this is, we have to consider the defining character of a *fluid*. A fluid, Kant maintains, is a type of matter whose parts can be displaced past one another by any moving force however small it may be. [28] It is crucial to recognize that displacement is different from separation. Whereas separation breaks the contact of the separated parts with one another, displacement does not produce self-contained parts with different surfaces that no longer touch. Moreover, although a liquid ’s parts may be displaced by any moving force, this does not mean that any moving force can separate those parts from one another. Displacement and cohesiveness are distinct. To illustrate this, Kant describes the travails of a tiny insect trying to make its way through a drop of water. [29] It can swim freely inside the drop, but when it attempts to break through the surface, it must contend with surface tension. Inside the liquid the insect encounters no other resistance than the inertia of the mass of the water it is displacing. To move through the water, the insect must exert moving force upon that part of the water. Because a liquid is freely displaceable, the other parts of the water do not offer any other additional resistance until they must be displaced. The insect must continue swimming to remain in motion through the drop, unless its initial exertion is sufficient to propel it to the surface of the drop. At each stage in its trajectory, the insect displaces an amount of water equivalent to its own volume, and the other parts of the water just change their position to accommodate the displaced water, without appreciable resistance. Differences in viscosity might

affect how easily the insect can swim through a liquid , but in every case, some displacement can be effected. None of the parts of the liquid become detached from one another. Continuous contact remains. The situation changes if the insect tries to penetrate the enclosure of the drop and make its way to the surface and then break through. Now the insect must contend with something distinct from liquidity as such, the cohesion of the water as exhibited in its surface tension. Surface tension is the form that a body 's cohesion takes when it is liquid , for although what is inside the liquid 's surface is freely displaceable, the surface maintains the liquid 's containment of its frictionlessly slipping interior, wherein nothing more than just inertial resistance is present, leaving aside what further physical features entail differences in viscosity.

On this account, something is solid when its parts cannot be freely displaced. In a solid , displacement is resisted by more than just the inertia of the mass that would be displaced. A solid has a different physical composition, whose relative rigidity opposes the extra resistance of friction to any potential displacement. This additional force involves more than just the mechanics of matter in motion. It depends upon the specific physical structure of solids.

Can Kant help us comprehend how this can be? Kant warns us that it would be wrong to locate the difference between fluids and solids in any different degree of cohesion of their parts. [30] This is because the liquid /solid distinction revolves around the physics of displacement rather than the physics of separation. Displacement and separation are two distinct physical processes and they are not necessarily connected. The cohesion of a liquid need not be less than the cohesion of a solid . Mercury may be more cohesive than pumice. What matters is rather whether displacement can occur without friction.

Kant offers a further definition of fluidity, which he identifies as the basic principle of hydrodynamics. [31] This principle is exhibited in any hydraulic system, which uses the specific property of liquids to move things. As Kant notes, fluid matters are those whose every point endeavors to move in all directions with precisely the same force with which it is pressed towards any one of them. [32] If pressure is applied to any part of a liquid , the same pressure is communicated to every other part of that liquid , which is what gives hydraulic systems their versatility. The omnidirectional transmission of force does not occur if something is solid . If one puts pressure on a solid piston in one direction, the pressure is communicated in that direction, not to the sides or to any other vector. What accounts for this difference? Two aspects of liquidity are crucial. On the one hand, a liquid has a frictionless, free displacement. On the other hand, this free displacement in no way diminishes the cohesion of the liquid . It maintains its cohesiveness in its free displacement, and together, these features allow hydraulic systems to function. By contrast, a solid cannot undergo "displacement" without jeopardizing its cohesion . At some point, the alteration of its shape will break its internal bonds, causing the solid to fracture and undergo separation, rather than displacement.

Although Kant conceives this difference of liquids and solids, he maintains that how rigid bodies are possible is still an unsolved problem. [33] He points out that the possibility of the relative rigidity of solids requires another ground of explanation besides the cohesion of its parts. [34] Cohesion does not suffice to distinguish fluids from solids. Both can have varying degrees of cohesiveness, just as both equally involve the fundamental dynamic forces of attraction and repulsion.

If cohesive force is not a deciding factor, then what is it that makes certain materials fluid and others solid ? What is it that makes solids resist the displacement of their parts so strongly that they break apart, overcoming the cohesion of the separating sections? Kant has nothing to offer in the way of a solution.

Does Kant's description of the difference between liquid and solid provide him with any basis for further distinguishing a gas from either liquid or solid ? Is cohesion a matter of indifference in distinguishing a gas from a solid or a liquid , as it was in differentiating the latter? Does a gas involve the same frictionless displacement that distinguishes liquids from solids? Like a liquid , a gas will fill up its container, altering its shape without separating into detached parts. Unlike a liquid , however, a gas will expand to fill a container with a volume greater than what the gas formerly possessed. A liquid will retain its volume and resist compression, which is what allows it to provide the hydraulic transmission of force in any direction. A gas , by contrast, will not only expand to fill a larger container, but undergo compression into a smaller volume, at least until the pressures build to the point of precipitating its liquification and then its solidification.

Is there any limitation to the expansion of a gas , when it is freed of external containment? Since a gas has mass of some amount, its parts will have some gravitational attraction to one another. Whether this is sufficient to contain the gas 's expansion, depends, of course, upon the power of whatever causes the gas to expand in the first place . In any event, a gas , unlike a liquid , does not seem to have enough cohesive force to hold back its dispersion. In this respect, the relatively weak cohesion of the gas does play a role in distinguishing it from liquids, as well as solids.

Although Kant may recognize this difference between gases and liquids, he can provide no explanation for it. He can describe the difference, but he has no physical basis to offer. Kant's dynamic theory of matter may allow for the expansion of a gas to have a continuous dispersion, without need of invoking empty spaces between discrete atoms. What the dynamic theory of matter cannot explain, however, is how any degree of expansion can constitute the specific differences that distinguish these three states of matter : liquid , solid , and gaseous. Kant will refer to differences in the density of air undergoing different degrees of compression, but he has no explanation of when and how such compression might lead to a nodal phase change, where gas becomes liquid .

Kant's whole discussion of cohesion involves an ambiguity that calls for remedy. On the one hand, cohesiveness is characterized as being a superficial, rather than penetrative force. It operates on the surface of bodies. On the other hand, cohesion is described in terms that render it something internal, penetrating the entirety of a material body , keeping its parts together. When cohesion is overcome, a body can rupture at any point internally. When it so ruptures, two separate bodies emerge with distinct boundaries that had been cohesive with one another. Of course, there were no such boundaries until the material body broke apart. Until then, the matter had a continuity in which each internal point was just a point surrounded by other points. Were these "points" of matter held together by something more than the original attractive force constitutive of matter? If so, on what basis? Where does this additional cohesive force come from and what can account for differences in its amount, such as distinguish different materials and, more generally, gases from liquids and solids?

These perplexities reflect a problem already evident in Kant's characterization of repulsion as a surface force. As Hegel points out, repulsion must also be a penetrative force to be constitutive of matter, for unless it operates within the interior of a body , that body fails to fill space and collapses. Nonetheless, at the surface of a body , repulsion operates in a different manner, resisting the intrusion of other bodies. It can do this, however, only by already infusing the interior of the material thing.

Kant's attempts to conceive density , cohesion , and some of the states of matter raise

problems that call for a genuinely physical account, going beyond his pure mechanics of undifferentiated matter in motion. Hegel will attempt to provide us with the conceptual resources that are needed.

8.4 Hegel's Account of Density , Cohesion , and the States of Matter

When Hegel introduced the first section of physics under the heading of the "Physics of the Universal Individuality ", he presented us with a threefold development. [35] It begins first with a determination of the physical qualities that exist as immediate, separate, self-subsistent entities comprising different types of celestial bodies, now distinguished in terms of their defining physical character, which revolved around the physical process light. Second follows a determination of physical qualities constitutive of the basic elements of nature . Third comes an account of the process that engenders these elements in what is described as a "meteorological" process.

To begin with, then, we have a differentiation in physical qualitative terms of independent bodies, which are bodies that were initially distinguished by their roles in the solar gravitational system. An independent central body , orbiting planetary bodies, and satellites and comets comprise the basic forms that bodies can take as these independent totalities in space given the workings of gravity that is intrinsic to matter. Now, these same bodies are physically distinguished in terms of light. Although light generally allows bodies to manifest themselves in a formal way that leaves them unaltered, light still has to emanate from some source. The central body , initially characterized by its gravitational role in the motions of the solar system , now takes on the physical character of the self-illuminating source of light. By contrast, all the other celestial bodies are dark matter that are illuminated by the central body , which now figures as a light emitting star . This relation seems to present two physical differentiations, but Hegel here distinguishes three other types of bodies that are essentially dark matter. He does so in a threefold way that should involve distinctly physical features. As we have seen, Hegel characterizes the lunar body as rigid, comets as having a dissolving physicality, and planets as containing both features. Are these distinctions ones that differentiate states of matter? Are lunar bodies solid , comets liquid and/or gaseous, and planets solid , as well as liquid and gaseous? The earth, as a physically qualified planet , is accordingly a concrete physical individual containing the states of matter that moons and comets separately possess. As such, the earth could be said to be domain in which all physical processes can occur, with the exception of the all-consuming nuclear fusion that renders stars worlds of fire (plasma). The earth can still be a habitat for fire (plasma) on a local scale, be it chemical or nuclear in origin, and this would allow planets like ours to be the place in which the full development of nature can proceed.

Hegel's differentiation of celestial bodies in terms of physical states of matter is well rooted in the gravitational dynamics of a solar system . The central body becomes a light emitting body of fire (plasma) due to its comparatively paramount mass , whose gravitational compression suffices to ignite nuclear fusion. It can be no surprise that the mass of plasma contained in the sun accounts for 99.9% of the matter in our solar system , with only the remaining 0.1% (most of which is contained in Jupiter) consisting of solid , liquid , and gas . To the extent that the rest of the universe consists of galaxies populated primarily by solar systems, the states of matter can be expected to have an analogous distribution.

Do Hegel's physical qualifications of celestial bodies follow necessarily from the absolute mechanics of gravitational systems? The key element on which the connection depends seems to reside in the light process, that is, in how the central body becomes self-illuminating, whereby its

matter takes on the physical state of fire (plasma). The explanation in terms of nuclear fusion itself depends minimally upon matter containing the differentiations of positive and negative charges by which nuclear particles are distinguished. In other words, matter must be electromagnetic in character, and thereby bound up with the light process, in order for there to be states of matter in general, and states of matter distributed among different celestial bodies. To show this, requires, of course, that an account be given of how electromagnetic polarity allows matter to take on qualitatively different states. On this basis, it is readily comprehensible how the gravitational preeminence of a star can make it a ball of plasma , how the lesser mass of a planet may enable it to contain not just solids, but liquids and a gaseous atmosphere, how the comparatively smaller mass of a moon may leave it a rock with too little gravity to prevent liquid to evaporate and vapor and other gases to escape into space, just as a comet will be too tiny to prevent its ice and liquid to dissipate. Admittedly, “super planets” like Jupiter and Saturn may be large enough to be orbited by comparatively massive moons that can keep hold of seas and atmospheres of their own. This qualification, however, only confirms how celestial gravitation ends up distributing the states of matter on a cosmic scale, as Hegel’s account suggests.

Having physically distinguished celestial bodies, Hegel proceeds to develop the process whereby the states of matter (identified as elements) transform themselves into one another. [36] Not surprisingly, he locates this process preeminently on planets like earth, where all the states of matter can be found. The process of the elements thereby takes on a planetary character, which he appropriately labels as “meteorological”. [37] Within the planetary domain the elements (states of matter) comprise elements of a whole within which they undergo a process akin to what Aristotle described in conceiving the transmutation of earth, water, fire and air into one another. This process cannot take place in stars, where fire or plasma consumes itself. Nor can it proceed on moons that contain solids, but no liquids or atmosphere. The dissipation of ice and gas on comets only provides a part of the meteorological process.

The full process of the elements, of the states of matter, thus takes place in its entirety only on planets, and not anywhere and everywhere in the universe. The physics of matter is such that the meteorological process is situated on a certain kind of celestial body , which is itself situated in a specific manner within a self-sustaining gravitational system of moving bodies. The process of the elements is thus terrestrial, in the broad sense of the term that can include not just planets but sufficiently massive moons. Thus, although pure mechanics may operate without restriction to place , the physical process of the states of matter has a determinate cosmic location, conferring some abiding value to Aristotle ’s distinction of terrestrial and celestial domains. That value is highly qualified, however. As Hegel’s situating of the process of the elements steadfastly shows, contra Aristotle , the terrestrial domain is a part of the celestial domain, rather than something falling outside of it. Celestial dynamics themselves determine the context for the different kinds of natural processes. Meteorological process will occur on planets or sufficiently massive moons, and on these locales, chemistry as well as life can develop.

Stars offer a much more physically restricted environment. It seems doubtful that a suns could have any chemistry. Chemical processes would seem to be impossible on stars to the extent that their nuclear furnaces make it impossible for chemical bonds to persist. Solids, liquids, and gases can all enter into chemical process, but the stripped particles of plasma seems to lack sufficient structure to undergo chemical reactions. It remains to be seen how life depends upon chemical process, but, by way of anticipation, we can surmise that the absence of chemistry on stars renders them devoid of life.

Although Hegel, like Aristotle , uses the term “element” to refer to what better comprises a

basic state of matter, he does pointedly warn against failing to distinguish the chemical elements from the physical “elements”. [38] The process of the physical elements is fundamentally meteorological, involving terrestrial phase changes of materials, where they alter their state without necessarily undergoing any change in chemical composition. By contrast, the process of the chemical elements involves specifically chemical reactions that occur in function of the chemically relevant identities of the different elements of the periodic table , which determine what molecular bonds they can forge with one another. Hegel, who has no periodic table before him, refers to how the differentiation of chemicals is contingent to an extent to which the differentiation of physical elements is not. What chemicals are found may be contingent, given how relatively unlimited are the possibilities of molecular construction, as exhibited most tellingly by the unique permutations of DNA. The states of matter , the physical elements, however, have a very limited diversity, and Hegel faces the challenge of uncovering the necessity of their differentiation that Kant was unable to establish.

Hegel seems to characterize the process of the physical elements in a very Aristotelian way, albeit within the very different context of a terrestrial environment that is itself part of the celestial universe of astrophysics. Once more we have earth, water, air, and fire. The term “earth” is employed by Hegel in a somewhat ambiguous way since, on the one hand, it is used to designate the totality of the planetary body , which contains all the elements and their process, and on the other hand, “earth” designates a single element, which, once more, will end up constituting a particular state of matter. Hegel is well aware that the four elements cannot be distinguished in terms of chemical relations, as if water were a molecule of hydrogen and oxygen. How then, does Hegel distinguish the element in purely physical, rather than chemical, terms?

The basic physical distinctions are familiar enough. Water, rather than being any chemical, is the liquid state of matter. Earth, rather than being any mineral, is the solid state of matter. Air, rather than being any chemical gas , is the gaseous state of matter. Fire, rather than being any form of chemical combustion, is the plasma state of matter. Does, Hegel, however, provide any physical account of how these states arise and how they exhaust the possibilities of the fundamental phase changes of matter? Hegel points out that we are dealing with the universal character of the elements [39] and any explanation of their process must focus on their universalities, which are individualized into existing forms of material that get transformed into one another. Although the physical elements are universal states of matter that any chemically distinguished element passes through, the physical elements actually exist, both simultaneously and sequentially. The further development of nature into chemistry will establish that the states of matter end up existing only as states of chemically determinate “elements”. Nonetheless, as phases generic to physical nature , they are conceptually prior to chemistry.

Hegel focuses first on air (gases), fire (plasmas), water (liquids), and earth (solids), [40] and addresses their process in terms similar to those employed by Aristotle , identifying active and passive dimensions, which each element possesses. The passive dimension of air (of gas) is exhibited in the transparency (or at least translucency) allowing light to pass through it. Another passivity of gas is exhibited in how it will occupy any container that encloses it. On the other hand air has an active dimension, without which, Hegel points out, we would be unable to smell anything. Namely, gas has a dissolving, corroding effect upon liquids and solids, causing the former to evaporate and the latter to dissolve and corrode, if often in a very slow, imperceptible manner. These passive and active dimensions indicate how one kind of element acts upon and transforms others. Matter in a gaseous state acts upon liquids and solids so as to facilitate their

phase change into another form. It would appear that gas has an active dimension that leads liquids and solids to change into a gaseous state themselves. In so doing, air enables solids to have an odor , dissolving into vapors that waft across space. What might provide a physical explanation of this process? Perhaps gases are characterized by having a certain level of kinetic energy that causes gases to communicate some of that energy to the lower kinetic activity of liquids and solids, leading liquids to evaporate and solids to abrade.

Water (the liquid state of matter) will similarly dissolve solids by communicating its greater kinetic energy to the relatively rigid array of solid material. Solids will thereby change in liquids, which then can evaporate and change into gas . Vapor, on the other hand, can, due to changes in pressure and temperature, lose some of its kinetic energy and condense into a liquid , and then, with further reductions in such energy , freeze into solid form.

Liquids, owing to their greater cohesion , will have an intermediary degree of passivity with regard to transmission of the light, resulting in translucency and refraction , which Hegel will address later in considering how light relates to different types of materials. Solids, for their part, may be totally opaque and resist the transmission of light, instead reflecting it to various degrees, depending upon their surface composition.

The preceding account, which treats the elements as states of matter , is on a few occasions, seemingly at odds with what Hegel says about earth and water. As earlier noted, Hegel at times refers to earth as our lonely planet , rather than as one of the states of matter that are found in our terrestrial environment. He also remarks that water itself has different states, changing from liquid to ice and from liquid to vapor. [41] Water, considered not as the liquid state of matter but as a chemical element does indeed undergo the phase changes common to physical substances. The same can be said of air, and to some degree of fire, if one considers it as a particular type of chemical combustion. These ambiguities are hard to avoid so long as the states of matter are identified as physical elements . Both Aristotle and Hegel succumb to this confusion, and philosophical physics can better jettison their invocations of earth, water, air, and fire, and of physical elements in general, and instead hold fast to the terminology of physical states or phases of matter, identified as solid , liquid , gaseous, and plasma . Their process may be understood to be meteorological to the extent that planets and sufficiently massive moons can host all phase changes of physical matter.

Although meteorology may be fully realized only on planets and massive moons, Hegel recognizes that the process of the elements still gets determined by something beyond the immediate planetary environment. He points to role played by heat transmitted by the light of the sun . The light emitting activity of the sun or of a star in general has obvious effects on meteorological processes. To the extent that heat physically consists of different levels of kinetic energy within physical substances, and that states of matter are distinguished by such levels and transformed by their change, it is intelligible how solar heat can drive meteorological process. As Hegel notes, the meteorological effects of solar radiation are mediated, of course, by the relative distance of planets to stars, the changes in that distance during elliptical orbits that produce seasons, and the rotations of planets that produce night and day, not to mention the tidal effects of lunar orbits and closely spaced planetary circuits. [42] In all these ways, the meteorological role of heat transmission by suns is particularized by the specifics of solar system dynamics, and only on this concrete basis, does meteorological process proceed. To the extent that solar dynamics involve a self-sustaining gravitational system, meteorological process obtains a self-renewing character reflecting the recurring variations in planetary heat absorption. In this way, stellar light produces weather.

Meteorology becomes affected by other factors, including planetary magnetic fields and volcanic activity due to molten cores, the metabolism of living organisms, and the technology of rational animals. Nonetheless, Hegel has good reason to identify light as a primary activating factor.

With regard to all these processes, it is important to recognize that meteorological dynamics cannot be explained by the mere metrics of planetary motion. Physical realities play a constitutive role and the philosophy of nature can only comprehend them when it transcends the limits of Kant's pure mechanics .

The irreducible character of meteorological process is reflected in modern and contemporary discussions of climate. [43] For example, the earth has been discovered to have a core that is rotating *faster* than the surrounding magma, which produces specific kinds of magnetic forces and generates heat . Hegel had himself remarked how the turning a planet on its axis will generate heat through internal friction. Recent observations seem to confirm that there actually is some such internal heat generation due to differences in rotation speeds within the earth's interior. Moreover, some speculate that the earth's core is molten due to gravitational pressures as well as the effects of internal radioactivity. Why would the molten core of the earth be rotating faster than the outer periphery of the planet ? Some speculate that this is due to the gravitational drag of the moon and the sun , which is causing the earth's rotation to slow down on its relatively rigid outer layers.

Similarly, attempts to explain the coming and going of ice ages depend upon processes that go beyond the dynamics of matter and motion and require the introduction of physical relations, as well as the impact of the emergence of life on earth.

It should be kept in mind, that the physical relations in question need not be specific to any particular chemistry. Meteorological processes can proceed on planets with completely different chemical compositions, where planetary cores are frozen balls of what exists as gases on earth, seas are filled with liquid methane rather than water, and atmospheres have little chemically in common with the air we breathe. Nonetheless, the same basic physical factors will generate changes in states of matter, producing weather, albeit of an other worldly sort. For this very reason, meteorological process has a universal physical character, which can be realized in an indefinite variety of chemical elements . The states of matter are in this respect particularities that are not yet fully individuated. They become individuated wherever they actually exist, for nowhere is there liquid , solid , gas , or plasma per se any more than anywhere is there just matter as such. Although the conception of nature has an inherent order, that order is not equivalent to a temporal order, an order of natural history. Nonetheless, the ordering of the idea of nature does reveal the structural presuppositions of different aspects of nature , which has ramifications for what natural features can be independently and antecedently realized. What follows will make this clear.

Notes

1. Kant, *Metaphysical Foundations of Natural Science*, 526–529, pp. 65–68.

2. Aristotle , *On the Heavens*, Book III, Chap. 5, 303b13–304b22, in *The Complete Works of Aristotle —Volume One*, pp. 496–498.

3. Aristotle , *On the Heavens*, Book III, Chap. 5, 303b13–304a5, in *The Complete Works of Aristotle —Volume One*, pp. 496–497.

4. Aristotle , *On the Heavens*, Book III, Chap. 5, 304a9—304b11, in *The Complete Works of Aristotle —Volume One*, pp. 497-498.

5. Aristotle , *Physics*, Book IV, Chaps. 8–9, 214b12–217b28, in *The Complete Works of Aristotle —Volume One*, pp. 365–369.

6. Einstein, *Relativity: The Special and the General Theory*, p. 176.

7. Aristotle , *De Anima (On the Soul)*, Book II, Chap. 7, 418b7–11, in *The Complete Works of Aristotle —Volume One*, p. 666.

8. Aristotle , *On the Heavens*, Book III, Chap. 7, 305b1–28, in *The Complete Works of Aristotle —Volume One*, pp. 499–500.

9. Aristotle , *On Generation and Corruption*, Book II, Chap. 1, 329a25–329b2, in *The Complete Works of Aristotle —Volume One*, p. 539.

10. Aristotle , *On Generation and Corruption*, Book II, Chap. 2, 329b20–30, in *The Complete Works of Aristotle —Volume One*, p. 539.

11. Aristotle , *De Anima (On the Soul)*, Book II, Chap. 2, 413b4, 415a4–5, in *The Complete Works of Aristotle —Volume One*, pp. 658, 660.

12. Aristotle , *De Anima (On the Soul)*, Book II, Chap. 7, 418a26–418b14, in *The Complete Works of Aristotle —Volume One*, p. 666.

13. Aristotle , *On Generation and Corruption*, Book II, Chap. 2, 329b18–33, in *The Complete Works of Aristotle —Volume One*, pp. 539–540.

14. Aristotle , *On Generation and Corruption*, Book II, Chap. 2, 329b31–32, in *The Complete Works of Aristotle —Volume One*, p. 540.

15. Aristotle , *On Generation and Corruption*, Book II, Chap. 2, 329b34–330a12, in *The Complete Works of Aristotle —Volume One*, p. 540.

16. Aristotle , *On Generation and Corruption*, Book II, Chap. 2, 330a25–29, in *The Complete Works of Aristotle —Volume One*, p. 540.

17. Aristotle , *On Generation and Corruption*, Book II, Chap. 3, 331a3–6, in *The Complete*

Works of Aristotle —Volume One, p. 541.

18. Aristotle , *On Generation and Corruption*, Book II, Chap. 3, 330b32–33, in *The Complete Works of Aristotle —Volume One*, p. 541.

19. Kant, *The Metaphysical Foundations of Natural Science*, 523–535, pp. 62–74.

20. Kant, *The Metaphysical Foundations of Natural Science*, 525–526, pp. 64–65.

21. Kant, *The Metaphysical Foundations of Natural Science*, 499, p. 36.

22. Kant, *The Metaphysical Foundations of Natural Science*, 533, p. 73.

23. Kant, *The Metaphysical Foundations of Natural Science*, 524, p. 62.

24. "Instead of a sufficient explanation for the possibility of matter and its specific variety from these fundamental forces, which I cannot provide, I will present completely, so I hope, the moments to which its specific variety must collectively be reducible (albeit not conceivable in regard to its possibility)", Kant, *The Metaphysical Foundations of Natural Science*, 525, p. 64.

25. Kant, *The Metaphysical Foundations of Natural Science*, 526, p. 65.

26. Kant, *The Metaphysical Foundations of Natural Science*, 526, p. 65.

27. Kant, *The Metaphysical Foundations of Natural Science*, 526, p. 65.

28. Kant, *The Metaphysical Foundations of Natural Science*, 526, p. 65.

29. Kant, *The Metaphysical Foundations of Natural Science*, 527, p. 66.

30. Kant, *The Metaphysical Foundations of Natural Science*, 527, p. 66.

31. Kant, *The Metaphysical Foundations of Natural Science*, 528, p. 67.

32. Kant, *The Metaphysical Foundations of Natural Science*, 528, p. 67.

33. Kant, *The Metaphysical Foundations of Natural Science*, 529, p. 68

34. Kant, *The Metaphysical Foundations of Natural Science*, 527, p. 66.

35. Hegel, *Philosophy of Nature* , §274, p. 86.

36. Hegel, *Philosophy of Nature* , §286–289, pp. 113–124.

37. Hegel, *Philosophy of Nature* , §286, p. 113.

38. Hegel, *Philosophy of Nature* , §281, p. 105.

39. Hegel, *Philosophy of Nature* , §281, p. 105.

40. Hegel, *Philosophy of Nature* , §282–285, pp. 108–113.

41. Hegel, *Philosophy of Nature* , §284, p. 111.

42. Hegel, *Philosophy of Nature* , Zusatz to §287, p. 119.

43. See Kenley Royce Dove ’s unpublished article (available at kdove@sanpolo.org), “The Concept of Climate and the Limits of Mechanism ”, for a relevant analysis of these discussions.

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9. The Physics of Particular Qualities

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Every material body passes through one or more of the physical states of matter , which can be found all together on planetary, terrestrial environments. Every material body further possesses particular physical features that Hegel addresses under the heading of the “physics of particular individuality ”. [1] These qualities involve the physical relations of specific gravity or density , cohesion , sound , and heat .

How are these relations physically constituted and should they be developed, following Hegel, not only subsequent to pure mechanics , but after the light process and the process of the states of matter (the so-called physical elements)? To clarify these questions, it is worth looking at some discussions of Aristotle and Kant that concern factors that underlie the physical developments at issue.

First, Aristotle ’s investigation of the void in Chap. 4 of the *Physics* [2] warrants consideration. Undergirding Aristotle ’s discussion is his presumption that *what is* is either substance or relations or features of substance. Any admission of a void would seem to violate this fundamental principle of being. [3] Aristotle , however, makes particular arguments about how and why nature cannot contain any void . He acknowledges some of the reflections that have led various thinkers of the ancient world to insist upon the existence of a void . These reflections often refer to the physical properties here at stake and, acknowledging their reality, then infer that there must be a void since they cannot be possible otherwise. Density , or specific gravity , is a prime example, as Kant’s debunking of the ancient atomists has shown.

In Chap. 7 of Book IV of the *Physics*, Aristotle points out that the void is sometimes associated with the determination of place , insofar as place is not to be identified with the bodies that occupy a location. [4] Since bodies can be moved, they must be detachable from any place they occupy, and if so, it seems that they must be displaced into a void and leave a void behind until some other physical substance enters that location. This suggests that the void is nothing but place without body .

Further, Aristotle points out, there are thinkers who associate matter with the void . [5] Some do this by conceiving matter per se, as completely unqualified, indeterminate potential to be equivalent to the void . After all, as pure potential, matter per se is not anything actual. It is indeterminate or nothing. Is however, the pure potentiality of matter equivalent to nothing or the void ? Or is the void a place that has the potential to be occupied by something? If the void is the location that can be occupied by something, it is not just indeterminate, but qualified with respect to place . Similarly, matter is not just nothing, since it is that which becomes actualized by being

formed into a component of substance.

Aristotle precludes any identification of matter with the void . [6] Even though matter may appear to be completely indeterminate, whose nothingness has some relation to its possible actualization as a material substance occupying a place , this does not render it a void . A void exists as empty space, but pure matter does not exist at all. Matter only has actual being by taking on some form. This is why the “matter” on which form is imposed in the craft activity of making is always an existing material with a specific nature , be it wood, marble, or some other physical substance.

That matter always exists as a formed material with a specific potential, given that form, fosters the view that matter is a substrate of change, as that which undergoes alteration. Matter, however, as pure potential, cannot undergo alteration because it has no determinate character. Only a substance can alter, since only substance exists with determinate qualities that can be replaced by their opposites, without destroying the nature of the substance. Matter can only be actual by being combined with a form as constituents of a substance. By contrast, on Aristotle ’s account, form can be actual by itself in the unique highest being that is immaterial pure actuality as self-thinking thought. Although this pure actuality cannot alter, what changes is not matter, but material substance, which alone undergoes alteration.

Early modern philosophers up through Kant depart from Aristotle ’s conception of substance by treating matter as if it can have an independent being subject to laws of its own. After all, Kantian mechanics is all about matter in motion, where the spatio-temporal location of bodies is determined with complete indifference to whatever other qualitative identity they may be perceived to have. Here matter in motion is determined without reference to any specific form that matter might possess. Nonetheless, it is presumed to have an actuality that is governed by material laws.

For Aristotle , however, since matter cannot be actual without form, and nothing is but substance and its relations and properties, there can be no void . Nevertheless, as Aristotle points out, some thinkers maintain that the very fact of motion requires that there be a void . [7] To move, something must leave its place behind, engendering a void , and move into an empty place . Indeed, at every point and moment of its travel, a void is produced and a void is supplanted by the departure and entry of the moving substance from one place into another.

How, then, can motion be without a void ? If something is to change its place , leaving one location and entering another, should not the new location be empty? Since two material substances cannot occupy the same place , motion seems to require that there be voids to leave behind and to enter.

On the other hand, could motion involve the compression or displacement of material substance, such that on leaving a place another physical entity takes up residence? Then motion could occur without any void . In that case, however, any continuing motion would require a continuing impetus to displace or compress what lies ahead. Then inertial motion (where a body remains in constant motion or at rest unless external force intervenes) would never be directly observable, which would hardly trouble Aristotle .

Similar arguments apply to the compression or expansion of a material substance. Whereas compression might be thought to leave behind unoccupied space, it might equally depend upon the entry of the compressing factors into the volume that is evacuated. By the same token, although expansion might seem to depend upon empty space into which to enter, it might equally involve pushing against material substance that occupies that space.

Given Aristotle ’s accordance of locomotive primacy to circular motion , such eternal

movement can only operate without a void through a circular replacement of material, where some heavenly material is periodically displaced and drawn into places continually left behind by the orbiting celestial bodies. Descartes, who identifies matter with extension, has to think of all motion in terms of vortexes where matter is just swirling around, with different parts of matter giving way to others without there being any empty space between bodies.

Can compression occur, however, without what gets compressed having to contain voids that collapse? This question is, of course, directly related to that of how bodies can have different densities. If one conceives compression in terms of internal voids being diminished, it seems easy to account for increases in density , just as conceiving expansion in terms of internal voids being enlarged, makes it simple to understand decreases in density . Kant's dynamic account of matter allowed him to explain difference in density through differences in attractive and repulsive forces, as if this could account for changes in density without recourse to any void .

Aristotle takes another route to avoid invoking the void . [8] Compression involves displacing other material and this leads to changes in density owing to how the displaced material compares in weight to that of the contracting material. The same explanation applies to expansion. What expands displaces material outside its former limits and this leads to change in density in relation to the different weights of the respective physical substances.

Aristotle points to another option involving meteorological process. [9] When water gets changed into air it expands. Here the change does not just involve quantitative changes in amounts and distributions of homogeneous material, such as the atoms of Democritus. It instead involves the qualitative physical difference between the elements (or states of matter) . Once again, this qualitative meteorological process can occur, generating compressions or expansions of material resulting in differences in density with no need to invoke the void to which atomists must appeal.

Aristotle makes a more radical argument in Chap. 8 of Book IV to the effect that, contrary to those who say that there can be no motion without a void , nothing could move if there is a void . [10] In here considering the void in regard to motion, Aristotle is not addressing the presence of a void inside bodies, as atomists invoke in explaining how bodies can have different densities. Here the void signifies the totality of space surrounding the places occupied by individual physical bodies. Aristotle attempts to show that any such void precludes motion. If we grant that material substances are in a void , Aristotle suggests, there are no resources with which to account for why they would be in motion to begin with, let alone move to one place rather than to any other. The void is indifferent not only to any direction or place , but to any particular substance. As utterly empty and devoid of substance, the void can have no determinate influence upon anything that lies within it.

Although Einstein's General Theory of Relativity may tie the geometry of space to the gravitational field of the bodies within it, [11] if space is just a void , there is nothing about it that would leave anything in it anywhere in particular, nor moving in any determinate fashion. The void as such provides no ground for anything in the void to change its place . Aristotle points out that so long as the void has a completely undifferentiated character, there is no more reason for anything in the void to move in any particular direction as come to rest.

This might seem to confirm the principle of inertia , for if something is at rest, the void appears to provide no cause for it not remain at rest, just as if something is moving, the void seems to offer no ground for it to stop. Inertia , after all, is based upon precisely the indifference of matter to any particular position in space-time . Aristotle , however, can hardly accept inertia if the different elements have a natural location. Accordingly, the void precludes inertia in that,

on the one hand, it offers no resistance to the natural tendency of something to find its natural location, and on the other hand, provides no impetus to keep something in motion. This is why if objects are in a void , motion can appear to be impossible, at least if it concerns locomotion distinct from how something seeks to occupy its natural place .

In this light, we saw how Aristotle explained the continuing motion of a material substance with air being set in motion by it and continuing to push it as it travels. [12] This was possible because no void interceded. Instead, the places continuously left behind by the moving substance were continually reoccupied by air, which pushed the moving substance along.

Given the natural tendencies of the elements and the problem of the void , what are the factors that, for Aristotle , can allow motion to have any determinate measure? Since physical substances move according to their nature , there can be no laws governing the motion of matter per se. Can there be, however, any laws quantitatively determining the motion of different elements (that is, physical states of matter)?

On the one hand, substances confront the resistance of whatever medium or obstacle lies along their path of movement. On the other hand, the substances have specific natures that impel them up to the heavens or down to the terrestrial surface or depths. There is, however, a further factor, which is any force exerted upon something in addition to the resistance it encounters and its own tendency to move in one direction or another. All these factors enter into the determination of a substance's motion. If, Aristotle suggests, substances inhabited a void , the possibility of motion having any specific determinacy would be obliterated. There would be no medium to exert its determinate resistance. There might be other substances in the void that could resist the further motion of another body or, alternately, collide with it from a different direction and provide an apparently determinable force that could affect that body 's motion in a calculable way. So long, however, as these substances are not already in contact, they must traverse the void , which offers no ground for them to do so.

The situation changes when the void is supplanted by a medium that separates material substances from one another. Then the motion of a physical object would be determined by its own heaviness or lift, on the one hand, and the specific resistance offered by the medium through which it must travel. The medium will diminish whatever speed would be contributed by the nature of the thing and whatever additional impulse might be given to it.

What accounts for the possible differences in resistance of media through which substances pass? One would expect a proportionality of resistance to the rarity of the medium. With zero density , that is, with a void , there would be a complete absence of any resistance. Aristotle suggests that this would entail an infinite acceleration of whatever is passing into a void . [13] Alternately, if something is somehow moving in a void its velocity should infinitely diminish the moment it enters any material medium of determinate density . There would then be no continuity between these two transitions, which defies the nature of motion. So there seems to be no way of admitting a void , since there is motion and it has continuity.

Moreover, we know that there are differences in motion depending upon the kind of medium moved through and depending upon what kind of a thing so moves. Since motion is always determinate and limited, the presence of a void is suspect.

9.1 The Void , Density , Elasticity , and Pure Mechanics

If, however, there is a mechanics of matter, where laws of motion apply, and inertia , fall , and gravitational systems operate, must there be a void , that is, empty space? Or do Aristotle 's arguments against the void still have relevance? Can a void be dispensed with if gravity attracts at a distance and matter is inertial, at least so long as gravitational attraction is either negligible, or supervened upon by mechanical impacts.

The acceptance of an aether of imponderable mass might seem to be a viable alternative, as it did to many modern physicists before Einstein. What does the aether actually do that empty space cannot? As Einstein notes, the aether might make the wave transmission of light more palatable. [14] It may seem to circumvent Hegel's objection that light cannot be wavelike since waves must be transmitted through some medium with mass , whereas light has none. An imponderable aether might seem to allow light to emanate in wave form, but Einstein's theory of special relativity shows how a stationary aether through which light travels is not needed to account for the dispersion of electromagnetic fields , nor is supportable in its own right. [15]

In the "General Remark to Dynamics" in the *Metaphysical Foundations of Natural Science,* [16] Kant briefly addresses the question of empty space and his considerations are worth exploring in connection with Hegel's treatment of the physical individualities of material substances. Kant is not concerned here with the void as empty space through which bodies move, but rather with the empty space as it may or may not figure in the physical variegation of objects. Whereas Kant attempted to explain the physical difference of solids and fluids, he did not address how gasses physically differ from liquids. The frictionless displacement of a liquid 's parts may depend upon an absence of the relative rigidity of solids, but it does not reflect any lesser or greater cohesion . Here we are dealing with something that goes beyond the interplay of the forces inherent in the dynamic construction of matter and in mechanics. One cannot explain the distinction of solid and liquid in terms of the dynamics and mechanics of matter, which determine bodies solely with respect to their mass and spatial-temporal position. We are here dealing with physical distinctions that go beyond what applies to the basic forces that pertain to matter as such—attraction and repulsion and the resultant constitution of gravity .

Kant's discussion of *elasticity* , which follows his differentiation of liquid and solid , introduces a further physical challenge. Kant here speaks about elasticity in a general way as that whereby a body reassumes its size or shape after these have been altered by some moving force. Kant specifically refers to size *or* shape since elasticity could apply to a body that does not have a fixed shape , such as a liquid , or, for that matter, a gas or plasma . Elasticity is not presented as something specific to any of the forms of matter. Kant acknowledges that elasticity can be possessed by both a liquid and a solid , and we might imagine it to apply to a gas or plasma . So long as some physical substance somehow resumes its size or shape after these have been modified by some moving force, elasticity is at hand.

Kant points out that we can think of elasticity in two ways: there can be *expansive* elasticity or *attractive* elasticity . [17] In the case of expansive elasticity , something rebounds to its initial size and shape after being compressed. In the case of attractive elasticity , something returns to its initial shape after being stretched or pulled apart.

Kant claims that attractive elasticity is derivative. It occurs due to the same attraction that causes the object's cohesion . [18] One is tempted to suppose that attractive elasticity is thereby derivative of the original attractive force that is co-constitutive of matter. Is cohesion , however,

equivalent to that original force of attraction , or something specific to the physical composition of a material object? After all, physical objects may occupy the same volume, but may have very different degrees of cohesion . This is true not only of the different states of matter , but of various solids, different liquids (perhaps reflected in different rates of evaporation), different gases (perhaps as reflected in different rates of condensation), and maybe even different plasmas.

Hegel pointedly distinguishes cohesion from the force of attraction, as well as from gravitational attraction. Whereas the attractive force that dynamically constitutes matter in conjunction with repulsion operates continuously throughout the volume matter fills, gravitational attraction works through ideal centers of gravity to which all matter is drawn. By contrast, cohesion prevents the material body from being deformed as well as from being drawn asunder into separated parts. The parts of a body can lose their cohesion without ceasing to fill the volume of space they occupy, as they become separated from one another. This indicates that cohesion is not reducible to the original force of attraction on which matter depends.

Moreover, cohesion shows its irreducibility to gravitational attraction by how a body ’s cohesion prevents it from altering its shape in function of the pull towards a center of gravity . For example, a solid may be cohesive enough to resist gravitational deformation of its shape . It should be kept in mind, however, that as much as water will flatten out when released from a supporting container under the pull of gravity , this does not signify that it loses its cohesion , for water will retain its volume, even if its shape changes.

How then are we to make sense of cohesion , and the forms of elasticity , if we cannot rely upon the force of attraction or gravitational attraction for an account? If attractive elasticity is derivative of cohesion , then we must first lay hold of what is constitutive of cohesion . It would engender attractive elasticity by resisting its deformation into a stretched shape and by pulling it back to its original form.

However this may occur, Kant considers expansive elasticity , where something rebounds after being compressed, as being neither original nor derivative of either original attraction or repulsion. Kant explains that the expansive elasticity of air rather derives from the “matter” of heat , which is intimately united with it. [19] In other words, when air expands, the expansive elasticity it exhibits derives from the heat it possesses. Heat is not the only physical factor that Kant characterizes as a type of matter. Like other of his contemporaries he also makes reference to a “matter” of magnetism , with which magnetic, and perhaps more generally, electromagnetic polarity is associated. The elasticity due to heat is to be distinguished from what Kant describes as the original elasticity that pertains to matter in general. [20]

Kant gives us no further account of heat , let alone of magnetism , but refers to both as if they were physical forms of matter conjoined with other material substances. However heat provides expansive elasticity to material bodies, each form of elasticity operates in respect to the moving force exerted by another body that has its own cohesion . Both types of elasticity are specifically physical reactions to action, which go beyond the mere mechanical law of equal action and reaction.

Hegel will note that cohesion and all the other physical “individualities” of bodies have a conditional character indicative of how they are inward. [21] That is to say, these physical individualities do not manifest themselves except in face of some external solicitation, some external act that brings them out from within the intrinsic physical character of the material body in question. In this way, attractive elasticity is something derivative of the external force that is pulling something apart. The physical object has its own internal cohesion and now, thanks to the external solicitation, its elasticity is made manifest by this added impetus. Similarly, the

derivative expansive elasticity of air derives from the addition of heat . By contrast, what Kant describes as the original expansive elasticity that pertains to matter in general would seem to refer to the basic force of repulsion . This elasticity is exhibited in how matter in general prevents other matter from entering its space by repelling it.

9.2 Kant and Chemical Process

Kant has little more to tell us about the distinction between mechanical and physical processes, but he does very briefly address the distinction between mechanical and chemical interaction in his *Metaphysical Foundations of Natural Science*, which is worth noting by way of anticipation in respect to how chemical process may be made possible by physical, and not just mechanical, process. [22]

Hegel's *Philosophy of Nature* will introduce chemical interaction on the basis of the most concrete physical process, which presupposes all the others that provide its own enabling conditions. Kant, by contrast, conceives chemical process by distinguishing it from mechanical relations. He does so by differentiating chemical dissolution from mechanical separation. [23] Kant begins by describing chemical action as being an action of bodies at rest where the combination of their parts is reciprocally altered through their own forces. This suggests that the parts in question are qualitatively distinguished, since otherwise, all that would occur would be an exchange of homogeneous matter, of only quantitative significance. In that case, the action would just involve a displacement of undifferentiated matter, where the excreted material would be replaced by qualitatively indistinguishable matter. Chemical, as opposed to mechanical process, will instead involve a dissolution and combining of qualitatively distinct constituents of material bodies. Moreover, the reciprocal qualitative alteration is not an action and reaction involving impact , since the bodies are at rest, albeit in sufficient proximity for the chemical reaction to ensue. In both regards, chemical process involves an alteration of composition that is not merely mechanical, not merely a matter of an external causality that is indifferent to the specific nature of what is altered. The composition of the bodies in question is somehow already qualitatively determined. By contrast, bodies in merely mechanical interaction are differentiated solely with respect to their mass and motion, and the moving force this involves. Chemical interaction depends upon other factors, since it involves dissolutions and recombinations of qualitatively differentiated material, which occur through something other than moving force. Some other kind of dynamic must be involved.

Although Kant acknowledges this, he remains convinced that reason is restricted to conceiving the pure dynamics and mechanics of matter, where laws of motion apply to bodies with indifference to what they are. Consequently, Kant maintains that reason can offer nothing necessary concerning chemical interactions, which at best, can be observed empirically, without genuine laws of chemistry ever being uncovered. Of course, law applies to subjects that law treats equally, with indifference to what qualitatively distinguishes them. As we have seen, the whole transcendental project, the whole project of critical philosophy, restricts objective necessity to material law. Accordingly, on its terms, philosophy can tell us nothing about chemical interaction.

Nonetheless, Kant does conceive another putative chemical process that he labels chemical penetration or absolute dissolution. This process involves, on the one hand, a solvent and something that is going to be made soluble in it. It might appear that this is a mechanical process, where bits of matter simply alter their position in space-time , so as to combine into a new aggregate. Here, however, something more is involved. As Kant acknowledges, absolute dissolution involves a distinctly chemical penetration of two materials. In a mechanical penetration, where parts of the two materials are interspersed, there are everywhere portions small enough to contain only one of the materials. By contrast, in the absolute dissolution of a

chemical penetration, no matter how far one divides the solution, one can never find any portion that does not contain both materials in combination. Whereas mechanical aggregations leave each material essentially separate from its counterpart, in chemical penetration, the materials merge with one another in a thoroughgoing interpenetration.

Kant offers no explanation for how chemical penetration occurs. Instead he remarks that it remains undecided whether there are dissolving forces in nature that are capable of effecting the complete dissolution of anything. [24] On the other hand, he admits, it is not clear why there could not be such forces. [25] What is needed is some explanation of *why* the chemically penetrated solution cannot be mechanically further divided into unmerged substances. Kant, however, has no further resources beyond the dynamic constitution of matter and pure mechanics on which to build. He lacks the polarity of positive and negative electromagnetic charge that would allow for chemically determinable atoms, which can enter molecular combinations that then can be altered in further chemical reactions.

Given Kant's lack of physical explanatory factors, one may wonder why Kant allows for something that could not be further dissolved into discrete qualitative substances. Kant does suggest that we might be tempted to think of matter being susceptible of an infinite division. However, if a solution is divided into smaller and smaller portions, their surface area increases relative to their volume. This makes the diminished portions increasingly susceptible to the dissolving action. Although an infinite division might appear to take an infinite time , as Zeno's paradox suggests, here the division accelerates the process of dissolution, so that complete chemical penetration in a finite time need not be precluded.

Kant has been arguing all along against the atomistic conception because of the dynamic conception of matter. No material body can be impenetrable, even if none can be compressed to a point. Chemical penetration does not involve compressing matter to infinitesimal points, but merging qualitatively distinct physical materials into a new material consisting in their combination. As Kant points out, if the penetration were merely a mechanical aggregate, one would have to ask why the dissolved solution would not separate owing to the effect of gravity . [26] What prevents this from occurring is the nature of chemical combination.

To shed light on such chemical bonding, Kant brings in *elasticity* . [27] The resulting solution of chemical penetration constitutes an elastic medium and its elasticity may suffice to explain why the solution does not separate again into the original solvent and the material to be dissolved. Elasticity resists gravity and allows the solution to retain its combined form. It also resists the dissolution of the physical object under the impact of external impacts, be they pulling or pushing. Are these effects, however, specifically relevant to chemical relationships? As Hegel's discussion of physical individualities shows, there are qualitative distinctions between materials that are not chemical in character. For example, solutions may involve materials that are distinguished by having different densities, rather than chemical affinities. Or materials might be mixed with one another and adhere to one another, without undergoing chemical combination. Adhesion is distinct from gravitational attraction and resists gravity , as well as external pulling and pushing.

Kant's discussion of chemical penetration presents two further points that Hegel will call into question.

First, Kant claims that chemical penetration can be found even where one of the two matters is not literally dissolved in the other, such as happens when the caloric matter, i.e. heat , penetrates bodies. [28] In this case, the caloric matter enters into the empty interstices allegedly between the matter of things. The solid substance that has the caloric matter in its interstices, in

its pores, that is, in its empty spaces, will not be chemically interpenetrated and will remain cold. If we opt for the idea of a caloric matter being an explanation of heat , then we must think of heat as penetrating things in the way in which there is chemical penetration, with a complete dissolution of a material with caloric matter.

Can heat be a material in its own right? Kant here speaks of heat as if it were a material substance that only affects other materials insofar as it interpenetrates them. Is caloric matter ever found by itself, however? If a heated material is a completely interpenetrated solution of a material with caloric matter, can these be separated out, leaving caloric matter isolated in its own right?

What is it about *heat* that would lead Kant to speak of it as if it were something that had an independent subsistence of its own? The transmission of heat seems to involve a communication of something that moves from one material to another. Just as a body can move from one place to another, making manifest how place is separate from a body (and thereby potentially a void), so the transmission of heat suggests that heat must be something separate from the materials it enters and leaves. Kant not only speaks of heat in this way, but also treats magnetism as something involving a magnetic matter. [29] Since the magnetism of one material can be transmitted to another appropriate material, this transmission process once more suggests that magnetism involves something separate from the materials from which and to which it gets communicated. If this communication is not chemical, involving the transformation of the materials involved, then it suggests that the materials have pores or interstices into which the magnetic or caloric matter can enter.

Does this require invoking empty space within matter, as the atomists maintain who Kant repudiated with his dynamic account of matter?

9.3 Kant and the Problem of Physical Form in Natural Science

In the beginning of the “General Remark to Dynamics”, Kant refers to what he identifies as the form problem of natural science, which concerns accounting for the potentially infinite variety of types of material things. Kant notes the limitations of the mechanical approach, which involves an atomistic conception presuming that there are indivisible material particles as well as a void . On this basis, bodies can be distinguished in terms of the arrangement of their smallest parts. In this respect, Kant identifies individual bodies as machines and takes these natural machines to be the subject matter of the mechanical natural philosophy, which he is rejecting. Here material things are distinguished in terms of their figure. This view presumes the absolute homogeneity of matter and thereby treats all physical differences as differences of shape and the aggregation by which material bodies are put together out of indistinguishable atoms. On this account, different densities are explained in terms of how many identical particles occupy the same volume, which will depend upon how much empty space is there as well. Three principles are here presupposed: the homogeneity of matter, the absolute impenetrability of its basic constituents, and the insurmountable cohesion of these fundamental particles out of which material things are composed.

Kant rejects all three of these presuppositions. In his discussion of the dynamic constitution of matter Kant argued against absolute impenetrability. Although matter would always be subject to relative penetrability, there could not be absolute penetrability since the repulsive force constitutive of matter would become infinitely concentrated as the volume of matter gets compressed to a point. Infinite rigidity, as well as infinite cohesion are equally impossible. Both would require infinite forces of repulsion or, alternately, of attraction, neither of which could be present in any object occupying a determinate space. Kant also rejects the absolute homogeneity of material substances, whereby only differences in shape would matter, on the basis of his dynamic explanation of matter. Although his dynamic account pertains to material bodies as such, irrespective of any qualitative differences, it allows for differences in density , at least if one accepts the notion that density depends upon the intensity of the combined forces of attraction and repulsion constitutive of matter. Since the body , so constituted, wields an attractive gravitational force that is a function of that body ’s mass , things of the same mass can occupy different volumes according to what degree the attractive force is countermanded by the repulsive force.

One might suppose then that objects of the same mass , which have the same force of attraction , can have different volumes and different densities insofar as the more voluminous object that is less dense contains more repulsive force than the object of equal mass that is denser. Hegel criticizes this view in his discussion of density under the rubric of specific gravity . [30] He points out that we really cannot make sense of density in terms of attractive and repulsive forces. Kant thinks the combination of attractive and repulsive forces allows one to explain differences of density without appeal to empty spaces, which he believes leads to the insupportable metaphysical claims of atomism. At face value, this idea seems empirically very implausible. If one compares the same mass of air and of a cube of iron and explains the greater volume of the air in terms of its greater repulsive force, one must wonder why the air can be so much more easily compressed and penetrated than the iron cube. To put the issue at rest, Hegel,

points out a simple difficulty with the notion that the same amount of matter could occupy a different volume due to differences in repulsive force. The moment one allows for objects of different density to have equal attractive forces but different repulsive forces, the problem arises of how a body can retain its volume if there is any difference in the magnitude of its attractive and repulsive forces. If the repulsive force is greater than the attractive force the object should keep expanding, whereas if the attractive force exceeds its repulsive force it should keep on contracting. So differences in density cannot be explained in terms of differences of repulsive force as Kant seems to suggest at this juncture.

If then attractive and repulsive forces must balance for any physical body to occupy a determinate space, can the magnitude of these forces be correlated with the mass within that volume, allowing different densities in function of how much attractive/repulsive force fills a determinate volume? The problem is that if attractive force remains correlated with mass , what would allow smaller attractive forces, balanced by equal repulsive forces, to occupy the same volume as larger masses? More than the dynamic forces constitutive of matter must be invoked to account for the difference.

In the same discussion Kant does point out that the possibility of empty space cannot be disputed even if we need not invoke it to account for differences in density . Kant maintains that empty space is required for all moving forces of matter. [31] On the one hand, space devoid of matter must be presupposed as a condition for the diffusion of all such forces. It is within empty space that matter moves and exerts its moving forces. In particular, attractive force presupposes empty space insofar as attraction operates not by contact, but at a distance. Something cannot be attracted by something else unless there is a separation. Separation, for its part, depends upon repulsion, for without repulsive force, attractive force would instantaneously eliminate any separation. Although Kant at times tends to characterize repulsion as a surface force, acting on contact, even then, repulsion should still create separation unless it is countervailed by an equal opposite force. Accordingly, even though we cannot allegedly experience e empty space, we must think its possibility. One might ask, of course, are we not experiencing empty space when we experience attraction, or repulsion for that matter? Kant had argued that attraction and repulsion are experienced differently. Repulsion, allegedly, is experienced directly through tactile pressure, whereas attraction is experienced indirectly through the experience of bodies moving at a distance. Does this mean that we experience empty space indirectly?

9.4 Hegel's Physics of Particular Individuality

Whereas Kant ventures to think about some of the physical features of material bodies for which his dynamics and mechanics provide few resources, Hegel seeks to conceive the physics of the particular individuality by which all material bodies are qualitatively distinguished. Hegel characterizes this domain of physics as an individualizing mechanics, insofar as it concerns the further differentiations that bodies as such undergo. [32] What lies at stake are the most basic, most minimal ways in which bodies become qualified, beyond the quantitative parameters of mass and motion. These are the most basic physical qualitative differentiations of material bodies insofar as they depend on nothing more than the mechanics of matter in motion and the even more elementary physical processes of light and the meteorology of the states of matter.

Hegel presents specific gravity , or density , as the first, most minimal qualification of material bodies. [33] This is followed by cohesion and its various forms. [34] Next comes sound , which presupposes density and cohesion insofar as sound involves the vibration of bodies, which rests upon their remaining cohesive and is conditioned by their density . [35] Last comes heat , which might be said to arise from sound , insofar as the internal vibration of a sounding body translates into the internal kinetic energy of molecular motion, in which heat consists. [36] Density , cohesion , sound , and heat are, then, the physical individualities of material bodies, which already involve light (or more generally, electromagnetism) and the process of the states of matter (solid , liquid , gas , and plasma). Conversely, it is important to recognize that none of the aspects of mechanics, of matter in motion, including inertial motion, fall , and gravitational systems, depend upon these physical qualifications.

Whether this is strictly true of the light process and meteorology is questionable. The formation of stars in gravitational systems involves changes in density and heat , if not cohesion and sound . After all, the gravitational compression that ignites fusion alters stellar density and generates heat . Similarly, since the source of light involves a specific state of matter, namely plasma , one further wonders whether the phases of matter deserve consideration prior to the nuclear ignition of light, even if meteorology cannot be and be thought in its entirety without moving from stars to planets and/or massive moons.

Moreover, the meteorological process whereby the states of matter transform themselves into one another does so in function of changes in temperature and/or pressure, which, at least in the case of evaporation, condensation, and plasma formation entail alterations in density .

A further question that needs to be addressed as we proceed is to what degree density , cohesion , heat , and sound are independent of, rather than conditioned by, the physical realities that Hegel subsequently treats under the heading of shape , magnetism , electricity, and chemical relationships.

In any event, in considering the physical individualities, we must keep in mind that these pertain to material bodies that already involve all the mechanical processes, including inertia , gravity , and solar systems, as well as light and the states of matter . To the extent that light makes possible the modifications of classical mechanics undertaken by Einstein in his Special and General Theories of Relativity , these are equally at hand, if they retain validity. Nonetheless, the physical individualities should, if Hegel's placement be taken seriously, require nothing more than these structurally antecedent aspects of nature .

In paragraph 292 of the *Philosophy of Nature* Hegel presents the division of the physical individualities. [37] The first individuating physical feature that is going to be imposed upon bodies

subject to inertia , gravity , light, and the states of matter is the abstract simple determinacy of specific gravity or density . It is *simple* in that it consists in a merely quantitative relationship of mass and volume that allows bodies to be distinguished from one another, without appeal to any further qualitative features, such as electromagnetic or chemical differentiations. Moreover, this simple individuating feature does not depend upon the states of matter, for differentiations of density apply to all these so-called physical elements . Mass and volume are already provided by the mechanical relationships of matter in motion. What makes density a distinctly physical feature is that it constitutes a qualitative difference distinguishing bodies from one another. It is physically basic, for all material substances have a determinate density , wherever their place in solar systems or whichever state of matter they presently possess.

The second physical individuality Hegel presents is cohesion , which presumably pertains to bodies that have a determinate density , but involve a further differentiating factor that may distinguish material substances of equal specific gravity . Cohesion involves a specific mode of connection of the parts of a material substance, one which goes beyond the attraction and repulsion constitutive of matter in general, as well as beyond gravitational attraction. This mode of connection is exhibited by how a material body resists the disruption of this connection.

Cohesion thus follows upon density in two respects. On the one hand, cohesion is not itself constitutive of differences in density , which depend only on the relation of mass to volume, and not on how cohesive the parts of a body may be. On the other hand, differences in density do not in and of themselves determine the physical nature of the connection of the parts. Density may bear upon the gravitational compression to which a body is subject, but not to its cohesiveness. This entails something more, even if the parts that are cohesively connected necessarily have some determinate density . Cohesion thus incorporates and follows upon density , and is not reducible to density .

Similarly, density leaves completely indeterminate the shape of a body . The same may be said of cohesion itself. Cohesion consists in the degree of connection of the parts of a body , which may be the same between bodies of different shapes, as well as remain constant when a body alters in shape . Cohesion pertains to the connection of a body ’s parts, rather than to the configuration of the body as a whole. In this sense, cohesion is a very simple and rudimentary individuating factor, which nonetheless supervenes upon the even more elementary physical features of light and states of matter .

Following *specific gravity* and *cohesion* , Hegel introduces what he calls the forms of the connection of the material parts of bodies that involve an “independently existing ideality”. [38] These take two forms: the merely ideal sublimation constitutive of sound and the real sublimation of cohesion constitutive of heat . Both forms bring what Hegel calls an “existing ideality” of the connection of the parts of physical substance, which already possesses a determinate density and cohesion . When Hegel uses the term *ideality* he is referring to the way in which something becomes an element of, that is a “moment” of something else that encompasses it. Sound and heat both comprise physical processes that envelop and supervene upon the density and cohesion of a material body . Density and cohesion are not eliminated but rather incorporated in physical processes that now mediate them in specific ways. Instead of being physical features that are immediately given, the density and cohesion of a material body will have their immediate givenness modified and re-established within a further physical process.

One way this occurs will be in sound generation , where a body ’s cohesiveness is both disrupted and re-established through its vibration and reverberation. The sound process involves

a “merely ideal sublimation” in that the disruption and removal of that disruption does not alter the specific gravity or cohesion of reverberating body . Sound is produced insofar as the vibrating body does not lose its cohesiveness, but returns to its original state with every completed vibration. By contrast, heat comprises a “real sublimation” of the heated material substance since it does alter density and cohesiveness, as already reflected in how heat plays a role in the meteorological process whereby bodies pass from one state of matter to another. [39]

Insofar as both sound and heat involve processes in which the density and connection of a body are modified, they do not involve the introduction of separate material substances, such as a sound -matter or the heat -matter to which Kant refers. Instead sound and heat are physical processes that supervene upon the given density and cohesion of material bodies.

Density and cohesion are both in play insofar as the disruption of cohesion can involve alterations of density . In sound vibration the shape and volume of a body is, at least momentarily, displaced to and fro (“ideal sublimation”), whereas in heat , shape and volume may undergo abiding change (“real sublimation”).

Hegel speaks of both sound and heat involving a mechanical individualization. [40] This is because through sound vibrations and heat transmission matter gets qualified in terms of its spatial-temporal determinations, either reverberating back and forth or altering its internal kinetic energy without changing its mass or other physical features until the nodal point is reached where heat makes matter pass from one state to another. Nonetheless, sound and heat comprise new dimensions of physical reality, distinct from inertial interaction of bodies and the movements of gravitational systems. As Hegel points out, with density , cohesion , sound , and heat , were are dealing with physical realities that comprise *inward* qualifications of bodies. These individuating qualifications are inward in that they manifest themselves on the basis of contingent external solicitations.

9.5 **Density**

This is evident first in regard to specific gravity or density . Hegel's account of density in paragraph 293 of the *Philosophy of Nature* is straightforward. [41] Density consists in the relation of the mass of a body to its volume, or alternately, of the weight of a body to its volume within a given gravitational field . Here, as Hegel notes, matter no longer comprises a uniform filling of space, in a purely abstract relation to a central body in a gravitational system. Instead density gives a body a specific inwardness to the abstract externality of spatiality. In gravitational systems, how bodies interact is indifferent to their density . All that matters is their mass , location, and velocity. Each weighted body has a center of gravity and inertial impacts, fall , and orbits in solar systems are determined irrespective of the differences in density that bodies may have. The fact that Jupiter may consist largely of gas and be much less dense than Earth does not affect how it functions in our solar system . It is its total mass and location that mandates how it affects the motion of the other bodies orbiting the Sun . Although mechanics operates with respect to matter as homogeneous, physics concerns the heterogeneous qualifications of material bodies, of which density is a primary example. In this respect, density is independent of gravity , even if gravitational attraction can compress matter, as in the case of stellar nuclear ignition. Density thus gives bodies a qualitative individuation.

Hegel himself criticizes atomistic theory's account of differences of density in terms of empty spaces and pores. He points out, however, that density cannot be conceived by following Kant in construing differences in specific gravity in terms of attraction and repulsion. In the addition to paragraph 293, Hegel exposes the incoherence of Kant's account of how something is less dense when forces of repulsion predominate and more dense when forces of attraction predominate. [42] As Hegel notes, Kant here persists in treating attraction and repulsion as if they were separate, self-subsistent forces. Neither, however, can be by itself, since attraction without repulsion instantaneously collapses matter into a point, whereas repulsion without attraction disperse matter to infinity, leaving it equivalent to a void . Moreover, Hegel suggests, if attraction and repulsion are not in equilibrium, the same consequences follow. So long as one of these coeval forces predominates over the other, there cannot be any determinate limit of density since nothing can prevent the body in question from either dispersing into nothing or collapsing into a point. The problem is similar to that afflicting Newton is his attempt to explain the motion of heavenly bodies in our solar system . Newton explained the elliptical circuit of planetary orbits by appealing to the waxing and waning disequilibrium of opposing centripetal and centrifugal forces. Not only was no explanation offered for why one of these forces increased relative to the other, but nothing was offered to prevent the orbiting planet from either leaving the gravitational field of the sun or falling into it when one force predominated over its counterpart. What remained a mystery is why the disequilibrium was reestablished, as an elliptical orbit requires.

How then are differences in density to be explained, if neither atomism nor disequilibrium between attraction and repulsion will do? Specific gravity consists in a simple quantitative relationship between two factors, already present in the world of mechanics on which physics supervenes: the mass of a body and the volume it occupies. There is a certain indifference between these two factors. Nothing requires that a determinate mass occupy any specific volume, or, conversely, that any volume of space be filled by any specific magnitude of matter. Indeed, the very indifference between the quantity of mass and the volume of its extension allows for

variability in their relationship. What, however, can explain how this variability can be physically constituted?

On purely mechanical terms, it is indeterminate how much mass occupies any particular volume. This indeterminacy indicates that relations of mechanism do not suffice to establish differences in density . Since determinate density pervades all the parts of a body , it is not something that refers to a center of gravity , as weight does. Density may be a simple quantitative relation, but bodies may have an irregular density .

Hegel has very little to say about density and one might ask just how much can be said about it in general. Hegel maintains that density depends upon comparison between bodies for its differentiation. [43] It only appears as a *quantum* by way of such comparison. This is similar to the general determinacy of intensive quantity or degree, which lacks extensive quantity, but has its specific magnitude in relation to the lesser and greater degrees that straddle its simple amount. So, for example, the tenth has its determinate magnitude of degree insofar as it has the ninth and the eleventh on either of it on the scale to which it belongs. Densities can similarly be represented as intensive magnitudes, which have their determinacy in comparison to one another. Unlike an extensive quantity, density does not consist of an aggregate of homogeneous parts that can be counted.

Density manifests itself in comparison, however, for strictly physical reasons. Inertial interactions, fall , and motion in gravitational systems may reflect the different masses of objects, but not their densities. The state of matter a body possesses will not indicate its relative density , unless, for example, one *compares* its liquid and gaseous states. What makes density a qualitative individuating factor is how its manifestation depends upon comparison with something else, the mass and volume of which are determinable.

That density is manifest in *external* comparison is indicative of how it is not determined by the *internal* relation of the attractive and repulsive forces constitutive of matter. Density is rather manifest only in relation to other physical entities.

9.6 Cohesion

Endowed with a determinate density , bodies are able to have a further differentiating feature above and beyond what mechanics and gravity accord to matter in general. This is cohesion , which distinguishes materials in a comparative way. Bodies are distinguished by their respective cohesions in their interaction with one another, which makes manifest this physical individuating factor. Cohesion involves more than the action and reaction of inertial interaction or gravitational pressure or density . This is evident in how bodies whose masses and velocities are equivalent, whose centers of gravity exert equal force, and whose densities are equal can still have very different cohesions.

How then is cohesion constituted? In paragraph 295 of the *Philosophy of Nature* [44] Hegel notes that the cohesion of a body involves a form immanent to it that posits a type of spatial relationship of its material parts that is distinct from that determined by gravity or density . This is not the form that Hegel will subsequently characterize as shape , which will involve such further physical configurations as the crystalline structure of a material body . Cohesion has a more general character that applies to material bodies, irrespective of their density and shape . Cohesion will not in and of itself mandate any particular shape . Instead, it will simply concern the cohesiveness of the parts of a material body , no matter what density and shape it may have.

Cohesion may be immanent to a material body , but it is not manifest by simply taking that physical object by itself. It manifests itself rather as a particular mode of resistance of the physical object in response to its mechanical interaction with other material bodies. Hegel characterizes the physical connection of cohesion as *inward* because it is only manifest *externally* in such interrelation with other physical bodies. [45]

Cohesion is thereby *conditioned* because it only gets exhibited in interaction with other bodies. Hegel pointed out that density is similarly conditioned in that differences of density only reveal themselves in the relation of bodies to one another. Like density , cohesion does not have a distinctive mark, shape or outward configuration of its own.

What then is distinct about cohesion ’s resistance to the mechanical push and pull of other bodies? Cohesion involves something over and above the action and reaction of inertial impacts as well as over and above the effects of gravitational attraction. On the one hand, cohesion involves a repulsion that resists the penetration of other bodies. On the other hand, cohesion involves an attraction that resists stretching and pulling by some external force and allows the material body to return to its original shape . These repulsions and attractions are not those generic to matter as such, but something distinguishing physical bodies, irrespective of their mass , motion, and density .

Together, these dual aspects of cohesion endow material bodies with an elasticity that provides the basis for a body to be able to vibrate and resonate with sound . To the degree that bodies of equal mass and density may have different cohesions, they may equally have different elasticities that will correspondingly condition their vibrations and sound .

The repulsion belonging to cohesion transcends the mechanical principle of action and reaction, which is determined solely in terms of the masses, velocities, and resulting moving forces of interacting bodies. Cohesion involves a further kind of resistance that operates in addition to the mechanical resistance of action and reaction. Bodies will resist differently according to what cohesion they possess. Cohesion comprises a physically specific way in which bodies hold themselves together, distinct from how they react inertially and gravitationally in

terms of their mass and motion. With cohesion , bodies resist one another in virtue of their qualitatively distinct internal composition, which accompanies those other interactions that pertain to the mechanics of matter in motion per se.

What then are the physical modes of the connectedness of material bodies that differentiate the forms of cohesion and, perhaps, indicate what underlies their operation? Hegel first distinguishes two types of physical cohesion .

First, there is what Hegel calls a “wholly indeterminate holding-together” of material, where one body adheres to something else. [46] This form of cohesion exhibits itself only in the relation of one material body with another, where their contact and subsequent resistance to separation manifests the special force of adhesion. This adherence is not gravitational attraction, which depends solely on the mass and distance of the bodies in question. Adhesion rather depends upon the qualitative physical character of the respective materials. As Hegel points out, the force of adherence is conditioned in a variety of ways. It depends upon both the composition of the material and the shape insofar as the latter determines how much surface area of the respective bodies can make direct contact. Adherence will be stronger the more the bodies fit one another, thanks to uniform surface texture and complementary contours.

Hegel describes such adherence as a *passive cohesion* . [47] This is because adhesion does not depend upon how a body holds its own parts together, but rather upon how its surface has a binding affinity to the surface of another material.

One might think that this relation of adherence has something to do with the forms of the elements, that is, the different states of matter . In the addition to paragraph 296 of the *Philosophy of Nature* , Hegel notes how water adheres readily to other materials due to the frictionless displaceability of its parts. [48] It makes things wet by easily filling the contours of whatever body it flows onto and thereby establishes the continuous surface contact facilitating adhesion. The relative rigidity of solids, by contrast, makes it more difficult for solid bodies to adhere unless their surfaces have matching textures and contours. Gases or plasmas, on the other hand, might fill whatever container they are placed in, but their adherence seems limited by the lack of cohesiveness that is exhibited in how a gas or plasma , unlike a liquid , expands to fill whatever space it is permitted to occupy. Little if any force seems required to separate a gas or plasma from any material body with which it has contact, provided there are no chemical reactions and the electromagnetic polarities these involve. Does adherence then rest upon the distinction of the states of matter? It would, of course, if differences in adherence correlated solely with what state of matter a material body possessed. Adherence, however, can vary among solids, as well as among liquids. This alone suggests that adherence is not simply a function of states of matter, but of the specific character, not to mention shape and texture (and surface tension) of a material body . Hegel expressly points out that adherence should not be associated with any of the elements, that is the elemental phases of matter. He notes that solid bodies, which have an inner cohesion different from that of liquids, nonetheless adhere provided their surfaces are not too rough and their contours fit. [49] If you put two flat pieces of glass together, one can barely get them apart. As long as solids can make close enough contact, they will adhere. Hence, adhesion is not a function of the distinction of elements, e.g. states of matter . It is a physical property in its own right that differentiates materials of the same state, as well as same density .

Hegel distinguishes a second form of cohesion from the *passive* cohesion of adhesion, which he identifies as *ordinary* cohesion . [50] This involves the cohesion by which a material body holds itself together, above and beyond the dynamic constitution of matter and gravitational attraction. This ordinary cohesion has a quantitative measure and manifests itself in the relation of one body

to another. Namely, when a certain weight or moving force is applied to a material body , its ordinary cohesion breaks down and the body severs into different parts.

Besides passive and ordinary cohesion , there are also *qualitative* forms of cohesion . [51] These have to do with how a material body holds itself together and retains its specific spatial configuration. Passive and ordinary cohesion have no specific spatial directedness, but rather apply to every part of a material body equally. Qualitative cohesion , by contrast, is distinguished by the direction in which it operates with respect to the geometric dimensions of a physical object.

Hegel differentiates three forms of qualitative cohesion in terms of the type of spatial configurations by which they hold a body together. [52] These are distinguished in terms of the geometric dimensions by which a physical object can hold itself together, above and beyond the mechanisms of the dynamic forces of attraction and repulsion constitutive of matter in general, and gravitational attraction. To begin with, there is a qualitative cohesion that exhibits punctiformity. Here a material body holds itself together around a point but not in other directions. Such cohesion manifests itself in the brittle character of a physical object that easily breaks apart into small parts which remain cohesive with themselves. On the other hand, there is a *linear* cohesion where things retain their connectedness in lines but not in any other direction. Thirdly, there is planar cohesion where the surface of a material body will be malleable and ductile without breaking apart. This is manifest when a physical object maintains its cohesion when it is stretched or contracted as well as when it is drawn out into fibers, all without fracturing into pieces. Surface tension in liquids is another example of such planar cohesion , which applies not to all parts of a material body , but to a specific geometrically defined aspect of its configuration. These together comprise the ways in which a physical object holds itself together in terms of the different spatial dimensions, irrespective of any further distinctions. Chemical reactions are not at stake, nor magnetic attractions. Instead, the forms of cohesion apply to physical bodies in general as qualifications that distinguish them from one another.

Hegel speaks of the various forms of cohesion as inward differentiations. As he emphasizes in the addition to paragraph 296 of the *Philosophy of Nature* , [53] these types of cohesion are inward insofar as they only show their character through the interaction of a material body with other material bodies. Only that external relation exhibits their connectedness, which otherwise is not immediately evident. Each form of cohesion shows its character only in physical interaction because each is a mode of resistance to the force of another physical body . It is not intrinsically connected to any outward configuration. The types of cohesiveness do not necessarily express themselves in the outer shape of a physical body .

9.7 Elasticity , Sound , and Heat

Elasticity follows upon the forms of cohesiveness insofar as a body is elastic in function of how its cohesion enables it to be externally deformed and rebound back to its original shape . Insofar as a physical body has some form of cohesion distinguishing it, it will automatically have some degree of elasticity .

Hegel appropriately introduces elasticity in paragraph 297 of the *Philosophy of Nature* [54] after having addressed the different forms of cohesion . He recognizes that elasticity depends upon cohesion since a body is elastic insofar as it exhibits a material continuity under the duress of external forces. This is not the mechanistic continuity matter possesses by filling space but a specific form of continuity by which a body resists being broken apart by overcoming external forces and reasserting its original configuration. As Hegel points out in the addition to paragraph 297 of the *Philosophy of Nature* , elasticity , like the cohesion it contains, displays itself in motion, where moving force is exerted on one body by another. Elasticity itself involves motion, the motion of the parts of a material body being pushed or pulled in some direction and then reverting to their original position. This is different from the action and reaction of bodies in inertial motion, where the moving forces are exerted by bodies in function of their total mass and velocity. Here movement occurs within the elastic body involving the back and forth motion of parts, rather than the movement of the entire body from one place to another.

Since elasticity depends upon a material body retaining its cohesiveness in face of external impetus, Hegel can speak of elasticity as cohesion displaying itself in motion. [55] Whereas cohesion itself is made manifest only when a moving force is directed upon a material body , elasticity manifests cohesion operating within the movement of the parts of a body .

Insofar as cohesion has various forms, the elasticity of a material body will reflect the type of cohesion it possesses. A physical object that has a punctiform cohesion will have a narrowly restricted elasticity , confined to the small parts that survive the brittle shattering of the body . Similarly, an object with linear cohesion will exhibit elasticity in line with that direction, rather than in deviation from it. By the same token, an object with planar cohesion will be elastic on its entire surface. In these ways, material bodies will exhibit qualitatively differentiated forms of elasticity in function of the kind of cohesiveness they have.

Just as elasticity and cohesion go together, so there is a connection between elasticity and density . As Hegel notes, even though cohesion is not directly tied to specific gravity , elasticity is ineluctably related to density . [56] Elasticity has a direct impact upon specific gravity in that elasticity involves the contraction and expansion of a body in its external relation to another pushing or pulling object. To the extent that this contraction and expansion involves the alteration of volume of the same mass , elasticity carries with it a transient change in density .

It should be kept in mind that elasticity , as well as cohesion , does not refer to the connections of atoms or molecules, as pertains to chemistry. [57] Instead, cohesion and elasticity refers to connections of the parts of material bodies without further qualification. Hegel recognizes that elasticity pertains to the cohesion of parts of a material body that transcend both whatever binds the elementary particles of atoms together or the bonds that tie atoms to one another in a chemical relationship. As Hegel notes, elasticity and cohesion pertain to the connection of parts of a material body that have no independently given existence, such as atoms and molecules may have. These parts have no preexisting boundaries. They only become separated when elasticity and cohesion breaks down. Consequently, where an elastic cohesive

material body ruptures is not internally at hand in any definite manner. The separation of a material body into parts depends upon the external forces that other material bodies wield upon it.

Elasticity and cohesion are thus very general types of physical determinations.

They provide the enabling physical conditions for sound , which depends upon a material body having sufficient cohesion and elasticity to vibrate in place and generate the sound waves that a surrounding medium can communicate. Sound involves not just matter in general, but a material body with the physical features of a specific gravity , a cohesion of a certain kind, and a corresponding elasticity .

Like density , cohesion , and elasticity , sound is made manifest through the external impetus of other material bodies. A physical material does not sound by itself, but is brought to resonate through interaction with other physical objects, including the resonation of sound waves emanating through some physical medium. Although, as Hegel will later note, animals can produce sound autonomously, [58] they do so by activating organs that bring some other part of the body to resonate.

The physical interaction that produces sound has a specific character. It involves the mechanical communication of motion in inertial relations, but adds to this the influence of density , cohesion , and elasticity , which transfers the moving force that would otherwise displace the entire material body and transforms at least part of it into a vibration of that body as a whole. The body set into vibration may well have its position altered, but sound pertains to the elastic movement to and fro of the parts of that body that together constitute its vibration. The sounding of the material body is a reaction to an action of another body , but it is determined by the specific qualitative form of the material bodies in question, whose own density , cohesion , and elasticity condition whatever vibrations result. Thanks to these physical qualities, the communicated motion becomes a *reverberating* motion, which cancels itself back and forth until it dissipates. The elastic cancellation of each movement elastically generates a contrary movement which undergoes the same elastic cancellation, renewing the vibration.

The movements generated by inertial impact and gravitational attraction may play a role in generating sound , but they are insufficient unless affected bodies have the requisite elasticity . This includes not just the sounding body , but any physical medium that transmits the sound . That medium must also have sufficient density , cohesion and elasticity to be moved to vibrate by the vibration of the sounding object.

Hegel distinguishes two basic forms of sound , pure sound and an impure sound that constitutes noise. [59] These are distinguished by the degree of unison of a body ’s vibrations. Hegel associates pure sound with a homogenous reverberation that penetrates the entirety of a body . By contrast, noise involves a plethora of heterogeneous vibrations that may or may not reverberate equally through all parts of the sounding body . When Hegel considers how heat gets generated, he will point to two corresponding ways in which heating occurs. On the one hand, the sounding object will become heated by the reverberation it undergoes. On the other hand, heat will be produced by friction, where one body rubs against another. In the former case, the pure sounding of unified vibration will itself increase the heat of a body , whereas in the latter case, friction will cause noise, whose inchoate vibrations will generate heat .

What is friction and how does it entail both sound and heat ? Hegel points out that friction consists in a form of vibration that only affects the surface of materials that rub against one another. [60] With friction, the elasticity of a material body ’s surface reacts to a moving contact with another body ’s surface, producing a vibration that does not penetrate through the entire

body , as in the reverberation of pure sound . Friction will depend on the configuration of the contacting surfaces, as well as the respective densities, cohesions, and elasticities of the respective bodies making contact. This factors are reflected in how different states of matter will be more or less susceptible to generating friction. The “frictionless” inner displacement of a liquid will mitigate against its surface providing sufficient resistance to generate friction. Similarly the free dispersability of a gas will also render its yielding surface a poor candidate for friction. On the other hand, if contacting solids have smooth matching surfaces, with little elasticity , friction will be relatively minimal.

Friction will produce sound that verges on noise since it will arise from the vibration of only a part of the material body , whereas pure sound emanates from the relatively unison reverberation that penetrates the body in its entirety. This can reflect the cohesiveness of the material body , as exhibited by how slapping a body of water can produce surface vibrations that do not reverberate comparably in its interior.

Like sound , friction will produce heat . The heat friction generates, however, will not be produced evenly throughout the entire body but will be concentrated on the surface, before being conducted through the rest of the object. Moreover, whereas sound involves a *recurring* motion, which continues to transmit kinetic energy throughout the reverberating body until it dies out, friction occurs along the vector where bodies rub against one another. If the contact occurs along a linear path, the heat produced by friction will be left behind as the surfaces move along, producing new intermittent warming along their trajectory. Rotary motion, of course, may generate friction around an axis, whose heat production continues to build in place .

In each case, what lies at stake is not fully determined by mechanics, but depends upon the qualitative physical features of the materials involved. This is evident in the physics of the heating of material bodies.

Sound and friction give rise to heat in virtue of the resistance offered to the vibrations that both produce. Although the reverberation of sound leaves the resounding body in place and relatively unchanged in configuration, it has a material cost. The recurring motion of vibration involves a disruption and reinstatement of the body ’s form, and this involves a recurring dissolution of the material’s cohesion through its internal reverberation. Energy must be expended to overcome the inertial resistance and cohesion of the vibrating body , and this not only leads the reverberations to diminish over time , but to transfer kinetic energy to the parts of the body that move back and forth. In sound , kinetic energy is communicated to all parts of the reverberating body , whereas in friction, it is concentrated upon those parts on and near the surface that is impacted.

Whatever heat is produced will then be transmitted to any material body that makes contact with a heated object. One can understand this in terms of how heat will involve a generalized kinetic energy effecting the parts of the body , without constituting the consolidated recurring motion of the body as a whole, as in sound reverberation. Insofar as all parts of the heated object have a degree of internal motion, whenever they make contact with another body , the impacts of the moving parts communicates their motion to the other body . Since the motion in question affects the parts individually, rather than in the unison wave formation of sound vibration, its relatively random motion will impact upon surrounding parts, which will then communicate the random motion they have received. In this way, heat will inevitably transmit itself through whatever materials come into contact, within and without individual bodies.

The motion in which heat consists is thus different from the inertial and gravitational motion of entire bodies in mechanical interaction, as well as the recurring motion of sound vibration. It

instead is a motion internal to the parts of material bodies, a motion that is not united in terms of wave formations, but rather random in its proliferation. Due to this random propagation, heat is susceptible to the stochastic or probabilistic statistical treatment employed in thermodynamic science. [61] Hegel does not further specify what the internal parts are whose kinetic motion comprises heat . Modern physics favors identifying heat as the kinetic motion of atoms and molecules, as opposed to the motion of the entire body to which they belong. On this basis, it becomes possible to apply quantum considerations to heat transmission, such as Einstein undertook. [62]

It is easy to see how sound , as well as friction, can increase atomic and molecular motion, which then communicates itself to adjacent atoms and molecules in the same body , as well as in other bodies that come into contact with them. What ultimately guarantees the transmission of heat is, Hegel maintains, the continuity of matter. [63] So long as matter is continuous, and one body is in contact with other material substances, heat will be disseminated. Whether heat can be transmitted across empty space in the form of electromagnetic radiation (e.g. infrared radiant heat) is a question that can only be addressed by considering the further physics of electromagnetism .

What can be considered in the present juncture of the physical individualities is how they impact upon the transmission of heat . Hegel recognizes that density and cohesion have a role to play. In considering their impact , it will be worth thinking back to meteorological process and how heat transmission played a role in the transformation of one state of matter into another.

Notes

1. Hegel, *Philosophy of Nature* , §290–307, pp. 124–158.

2. Aristotle , *Physics*, Book IV, Chaps. 6–9, 213a12–217b28, *The Complete Works of Aristotle* —Volume One, pp. 362–369.

3. Parmenides had earlier dismissed empty space by arguing that since nothing is not and only being is, no void can be. Heisenberg points out that Parmenides' rejection of change is tied to this rejection of empty space, writing, "since all change requires empty space, as he assumed, he dismissed change as an illusion." See Heisenberg, Werner , *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper Collins, 2007), p. 38.

4. Aristotle , *Physics*, Book IV, Chap. 7, 213b32, *The Complete Works of Aristotle —Volume One*, p. 363.

5. Aristotle , *Physics*, Book IV, Chap. 7, 214a14, *The Complete Works of Aristotle —Volume One*, p. 364.

6. Aristotle , *Physics*, Book IV, Chap. 7, 214a15–16, *The Complete Works of Aristotle —Volume One*, p. 364.

7. Aristotle , *Physics*, Book IV, Chap. 6, 213b5–6, *The Complete Works of Aristotle —Volume One*, p. 363.

8. Aristotle , *Physics*, Book IV, Chap. 7, 214a33–214b3, *The Complete Works of Aristotle — Volume One*, p. 364.

9. Aristotle , *Physics*, Book IV, Chap. 7, 214b3–4, *The Complete Works of Aristotle —Volume One*, p. 364.

10. Aristotle , *Physics*, Book IV, Chap. 8, 214b18–215a19, *The Complete Works of Aristotle — Volume One*, p. 365.

11. Albert Einstein , *Relativity: The Special and the General Theory*, p. 83 ff.

12. Aristotle , *Physics*, Book IV, Chap. 8, 215a16–19, *The Complete Works of Aristotle — Volume One*, p. 365.

13. Aristotle , *Physics*, Book IV, Chap. 8, 215b20–23, *The Complete Works of Aristotle — Volume One*, p. 366.

14. Einstein, *Relativity: The Special and the General Theory*, p. 166.

15. Einstein, *Relativity: The Special and the General Theory*, p. 166.

16. Kant, *Metaphysical Foundations of Natural Science*, 523–525, pp. 62–64.

17. Kant, *Metaphysical Foundations of Natural Science*, 529, p. 68.

18. Kant, *Metaphysical Foundations of Natural Science*, 529, p. 68.

19. Kant, *Metaphysical Foundations of Natural Science*, 529, pp. 68–69.

20. Kant, *Metaphysical Foundations of Natural Science*, 530, p. 69.

21. Hegel, *Philosophy of Nature* , §291, p. 125.

22. Kant, *Metaphysical Foundations of Natural Science*, 530–535, p. 69–74.

23. Kant, *Metaphysical Foundations of Natural Science*, 530 ff., p. 69 ff.

24. Kant, *Metaphysical Foundations of Natural Science*, 530, p. 69.

25. Kant, *Metaphysical Foundations of Natural Science*, 531, p. 70.

26. Kant, *Metaphysical Foundations of Natural Science*, 530, p. 70.

27. Kant, *Metaphysical Foundations of Natural Science*, 531, p. 70.

28. Kant, *Metaphysical Foundations of Natural Science*, 532, pp. 71–72.

29. Kant, *Metaphysical Foundations of Natural Science*, 532, p. 71.

30. Hegel, *Philosophy of Nature* , Remark to §293, p. 127.

31. Kant, *Metaphysical Foundations of Natural Science*, 534, p. 74.

32. Hegel, *Philosophy of Nature* , §290, p. 124.

33. Hegel, *Philosophy of Nature* , §293, p. 126.

34. Hegel, *Philosophy of Nature* , §295–298, pp. 130–134.

35. Hegel, *Philosophy of Nature* , §300–302, pp. 136–147.

36. Hegel, *Philosophy of Nature* , §303–306, pp. 148–156.

37. Hegel, *Philosophy of Nature* , §292, p. 126.

38. Hegel, *Philosophy of Nature* , §292, p. 126.

39. Hegel, *Philosophy of Nature* , §302, p. 147.

40. Hegel, *Philosophy of Nature* , Zusatz to §300, p. 138; Zusatz to §302, p. 147.

41. Hegel, *Philosophy of Nature* , §293, p. 126.

42. Hegel, *Philosophy of Nature* , Zusatz to §293, pp. 128–130.

43. Hegel, *Philosophy of Nature* , §291, p. 125.

44. Hegel, *Philosophy of Nature* , §295, p. 130.

45. Hegel, *Philosophy of Nature* , §295, p. 130.
46. Hegel, *Philosophy of Nature* , §296, p. 131.

47. Hegel, *Philosophy of Nature* , Zusatz to §296, p. 131.

48. Hegel, *Philosophy of Nature* , Zusatz to §296, pp. 131–132.

49. Hegel, *Philosophy of Nature* , Zusatz to §296, p. 131.

50. Hegel, *Philosophy of Nature* , §296, p. 131.

51. Hegel, *Philosophy of Nature* , §296, p. 131.

52. Hegel, *Philosophy of Nature* , §296, p. 131.

53. Hegel, *Philosophy of Nature* , Zusatz to §296, pp. 132–133.

54. Hegel, *Philosophy of Nature* , §297, p. 133.

55. Hegel, *Philosophy of Nature* , Zusatz to §297, p. 133.

56. Hegel, *Philosophy of Nature* , §298, p. 134.

57. Hegel, *Philosophy of Nature* , Remark to §298, p. 134.

58. Hegel, *Philosophy of Nature* , §351, p. 353.

59. Hegel, *Philosophy of Nature* , Zusatz to §300, p. 139.

60. Hegel, *Philosophy of Nature* , Remark to §300, p. 137.

61. See Heisenberg, *Physics and Philosophy*, p. 73.

62. See Heisenberg, *Physics and Philosophy*, p. 6.

63. Hegel, *Philosophy of Nature* , Remark to §304, p. 150.

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10. From Thermodynamics to Electromagnetism

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The physical processes of nature both incorporate and transcend the mechanics of matter in motion by constituting what can be called the dynamics of electromagnetic matter. Whereas Kant limited reason's grasp to pure mechanics , Aristotle was at pains to grant matter any laws or forms of its own, leaving him to begin his account of nature with material substances whose specific character was tied to a determinate place and type of motion. Hegel, by contrast, has attempted to think space, time , inertial motion, fall , and gravitational systems as elementary natural realities that provide the constituents enabling matter to become qualitatively differentiated in physical processes that mechanics leaves undetermined. Hegel recognizes that light is the minimal feature of physical reality on the basis of which all further physical differentiations proceed.

Although Hegel does not directly identify light with electromagnetic radiation in general, if one acknowledges this connection, then Hegel's commencement of physical process with light anticipates Einstein's theories of special and general relativity as well as quantum "mechanics". Both of these landmarks of modern physics address how material nature as electromagnetic takes on new determinations that cannot be fully captured by the "classical" mechanics of Newtonian science. Once nature encompasses not just undifferentiated matter, but electromagnetic fields and the polar charges these involve, accommodating the observed invariance of the speed of light requires re-determining the motion of bodies in different inertial frames of reference as well as how gravitational fields involve the acceleration of bodies. To insure that the velocity of light is never changed nor exceeded, special and general relativity introduce a dilation of time , a contraction of distance, and an increase in mass as objects accelerate towards the speed of light. Similarly, once the most elementary constituents of matter are acknowledged to have electromagnetic charge, the relations of their position and momentum must be re-determined with respect to both the physical process of observing them with light and the observed symmetries of wave and particle . Although Hegel does not provide any of the specific modifications of classical physics that Einstein and quantum mechanics introduce, he does attempt to think through how the different physical processes of nature develop on the basis of the elementary reality of light. In so doing, he unfolds a progressive constitution of the qualitative physical reality of nature that contains, but is irreducible to, the mechanics of matter in motion.

In following Hegel's presentation we must consider to what degree it retains its coherence as we proceed along its unfolding of physical nature . As we have seen, Hegel began by considering

light in conjunction with the process by which light is originally emitted. This involved considering how gravitational systems generate stellar sources of light, as well as dark bodies that these illuminate. If the stellar generation of light involves nuclear fusion engendered by the gravitational contraction of solar bodies, it would be necessary to take into account the nuclear structure of matter, which rests upon the electromagnetic differentiation of positive, neutral, and negative charges distinguishing the constituents of atomic nuclei. One could consider nuclear fusion in general without addressing how different chemical elements can have different nuclei and electron shell formations. Nonetheless, one would have to have at hand the relation of electromagnetically differentiated matter and energy , including the convertibility of mass into energy and energy into mass (e.g. $E = mc^2$). The emission of light from nuclear fusion would also involve understanding stellar heat as a form of electromagnetic radiation that may traverse empty space. Such heat would be distinct from the internal kinetic motion of the parts of a material substance, which communicate their energy to other materials with which they make contact. Such parts might further figure as chemically individuated atoms or molecules, the nuclear and electron shell configurations of which constitute the enabling conditions for specific chemical interactions.

The differentiation of states of matter , as well as physical individuating qualities of density , cohesion , and elasticity may not rest upon chemical processes, as Hegel’s account acknowledges. The physics of atomic structure, however, still provides an important resource for understanding how different chemical elements , distinguished by the number of positive and neutral particles in their nuclei and negative particles in their electron shells will be solid , liquid , or gaseous at different temperatures. These electromagnetic aspects of physical structure also help account for the relative density , cohesion , and elasticity of different materials, providing resources of which Hegel does not himself avail. Since sound , as well as heat generated by the internal motion of the parts of materials, depends upon density , cohesion , and elasticity , the sounding and thermodynamics of physical bodies is equally predicated upon the relevant features of atomic and molecular structure.

10.1 The Ambiguous Position of Hegel's Account of Thermodynamics

Although Hegel thematically introduces heat as a physical outcome of sound and friction, he also acknowledges that heat emanates from the solar emission of light and plays a constitutive role in the meteorological process whereby matter passes through its different states. These different placements of heat in physical process raise the question of how they are united and what thermodynamic process generally incorporates.

The heat emitted in stellar light may be understood as an electromagnetic radiation that traverses empty space like light itself. When such radiation heats a material substance, it will do so by imparting additional kinetic energy to the parts of that substance. This will not occur by the inertial impact of its own material moving parts, insofar as electromagnetic radiation has no mass of its own, whether it be wave or particle. The heating produced will rather involve a transfer of electromagnetic energy to material upon which it radiates, which becomes transformed into kinetic energy .

Hegel never acknowledges the conversion of matter into energy and energy into matter by which nuclear fusion enables stars to generate their light and heat . Hegel instead suggests that solar ignition rests upon a friction arising from the internal rotation of stellar matter, which would connect the heat of solar radiation with the heat arising from sound and friction, determined among the particular individualities of physical process. Nonetheless, Hegel can hardly deny that the heat of solar radiation emanates across the solar system , without being transmitted by sound or friction, let alone through the contact of communicating the kinetic energy of their temperatures.

When Hegel situates the meteorological process as fully present in planets or large moons, he is effectively acknowledging how the heat generated by stellar radiation plays a constitutive role in the transformations of states of matter into one another, as manifest in planetary weather. More generally, the transformation of states of matter into one another appears to involve change in temperature and/or pressure. This suggests that thermodynamics is ingredient in the states of matter, rather than being limited to the particular physical processes of sound and friction. Although weather may be, at least in part, precipitated by the electromagnetic radiation emitted by stars, the change in states of matter seems to involve the heat consisting in the standing random motion of the components of materials, be they atoms, molecules, or larger conglomerations. It is the change in such random motion that eventually arrives a nodal point where the state of matter becomes transformed. Insofar as that is the case, the heating produced by sound and friction can be regarded as a particular thermodynamic process specific to those physical phenomena.

As we have seen, Hegel applies the term "ideality" to both sound and heat . Hegel always uses the term "ideality" to refer to factors that lose their immediacy by becoming incorporated in something of which they are components. In the case of sound , the physical components of a material body become engulfed by the vibration with which they sound . The vibration operates with respect to and in terms of the particular cohesion and density of the object in question. Accordingly, the transmission of sound exhibits what is physically specific to the material that vibrates. Since their vibration leaves bodies rebounding repeatedly, it leaves them largely unperturbed, continually returning to their initial condition. Heat equally pervades each object,

engulfing it in the random kinetic motion of its parts, whose temperature indicates the magnitude of such internal movement. Unlike sound , which reverberates back and forth, heat does not continually reaffirm the configuration and cohesion of the object. Instead, heat dissolves or congeals the object's configuration, altering its cohesion and density .

How much energy is expended in altering the heat of a material will be relative to its specific density and type of cohesion , to the extent that these factors affect how easily the body 's parts can be made to move more or less rapidly. Density conditions how much energy is required to increase a material's temperature, since the more mass the parts have in a given volume, the more force must be communicated to increase their kinetic motion in aggregate. Similarly, different types of cohesion will impact a material's temperature change by resisting the motion of different parts of that material in different directions. Accordingly, as Hegel observes, materials will transmit heat in ways relative to their physical composition. Their specific densities and cohesion will give them distinctly different conductivities of heat [1] and distinctly different thermal capacities. [2]

Together, density and cohesion will thereby also affect at what temperature a certain material undergoes its phase transformations into a different state of matter. Thermodynamics is thus conditioned by the physical particularities of material substances. These physical particularities may not impact the overall mechanical interaction of bodies, unless their elasticity and cohesion affects how they absorb moving force. Sound and heat , however, are intimately connected to these internal differentiations that physical composition constitutes.

The physical conditions of heat transmission, which depend upon contact between physical materials, is partly reflected in the heating of objects by stellar radiation. The production of electromagnetic radiation in stellar fusion does not depend upon the interaction of bodies, but rather rests upon a star 's own gravitational compression to precipitate the transformation of matter into energy . Nonetheless, solar radiation will alter the heat of illuminated bodies in function of how their own physical composition affects how much energy is needed to alter the internal random motion of their parts. In the case of these bodies of relatively dark matter, the generation of heat will still largely depend on relation to other physical entities.

Conversely, as Hegel notes, the heating of objects to a sufficient degree itself generates light and radiant energy , which may or may not be accompanied by the release of chemical energy through combustion. [3] Hegel associates this production of radiant energy to heat 's dissolution of material bodies, which effects "a negation of matter still tied to matter", [4] suggesting something akin to a transformation of matter into energy . Although such radiant energy can transmit heat without direct material contact, whatever it heats will change its temperature in function of its physical particularities.

10.2 Shape and the Physics of Total Individuality

When Hegel proceeds beyond the particular material realities of density , cohesion , elasticity , sound , and heat , he turns to a different type of physical qualification, which he develops under the rubric of the physics of total individuality . [5] The preceding physical features were all characterized as inner and conditioned because they either were made manifest through external interaction of material bodies (e.g. density , cohesion , and elasticity) or were produced by one body acting on another (e.g. sound and heat). By contrast, the physical realities of "total individuality " are inherent in the structure of material bodies and manifest themselves directly.

Accordingly, when Hegel develops the so called physics of total individuality , he is determining how material bodies individuate themselves not in a conditioned manner, but freely. To begin with, the physics of total individuality concerns how bodies have a "shape " of their own, inherent in their specific physical structure. Material bodies are in a position to have such "shape " because they already possess the particular physical features which are conditioned by their interaction with one another. That is, in having a specific density , cohesion , elasticity , sound , and heat conductivity and thermal capacity, a material body possesses the internal structure enabling it to be qualitatively distinguished from others, above and beyond its mass , velocity, astronomical identity, and state of matter.

When Hegel introduces as the first form of physical total individuality , he is addressing the most basic way in which physical bodies are individuated not in reaction to some external stimulus, not as conditioned, but in terms of the form that they have in and of themselves. The German word Hegel uses for such shape is *Gestalt*, which is not the same thing as *eidos* or "form" in any Platonic or Aristotelian sense. Whereas the *eidos* or form has an intelligible, non-sensible being, shape here involves a specific type of physical configuration that has a spatial component. As independent, this shape is not generated by gravity , nor by the impact of bodies in some mechanical compounding. Shape rather comprises a self-subsistent physical form distinguishing a material entity.

This most minimal total individuality is shape in a very rudimentary sense. It does not involve the specific unity living organisms, nor for that matter the other physical processes which Hegel subsequently treats as the two further stages in the concrete development of the total individuality of physical entities: electrical and chemical composition. Insofar as shape precedes the determination of life, it will involve configurations that are endemic to physical things, be they inorganic or organic. Although organisms may have distinctive forms of their own, they will incorporate the physical shapes that here lie at stake. Conversely, shape will be constituted on the basis of the mechanical and physical processes that are already at hand.

Hegel characterizes shape has having three successive developments: first, the most immediate, almost indeterminate shape of non-crystallized physical material; second, magnetism ; and third crystal organization.

What is magnetism doing among the dimensions of shape and what does it here signify? So far, Hegel has not yet introduced any polar relations of positive and negative forces, which might be considered generic to electromagnetic phenomenon, as well as constitutive of atomic structure and molecular organization. The mechanics of matter in motion and gravitational systems have opposing forces of attraction and repulsion, but these are generic to matter, which is not therein differentiated into positive and negative particles and their corresponding force fields. As we shall see, however, magnetic polarity will play a crucial role in how the shape of physical

material becomes differentiated and plays a differentiated role in physical process.

Hegel further differentiates the three dimensions of shape in respect to light and the elements or states of matter . First there is the general way in which an individual body has a shape on its own. Then there are the ways in which these bodies get particularized in virtue of how their shape relates to light and the elements. These particularizations depend upon the general shape a body has in its own right and show how that shape affects the modifications wrought by light and the transformations from one state of matter to another. Here Hegel is trying to give a physical account of some more of the secondary properties that are regarded as purely subjective by those who subsume everything under mechanism . Whereas Hegel gave an account of sound and heat in respect to conditioned physical particularities, here he addresses color , smell, and taste .

Hegel also introduces electricity in this context. Whereas shape gets particularized in relation to light and the phase transformations of matter, electricity involves a relation between independent bodies in which they are physically differentiated in and through the electrical process. This will provide a bridge to the third stage of the total individualities: the chemical being of physical substances.

On Hegel's account, chemical process constitutes the third dimension of physical total individuality . As such, it incorporates the two prior dimensions and precedes organic nature , which incorporates it in turn. In chemical process material bodies are individuated vis-á-vis one another and they interact chemically in terms of their specific chemical individuality . This chemical interaction will involve processes in which chemically individuated substances combine and get broken down in terms of their chemical identity.

Chemical interaction will take physical nature to the threshold of life, providing, together with all the preceding incorporated physical processes, all the enabling conditions for organisms to arise. Strictly speaking, all the physical processes on which chemistry rests should not themselves involve chemical interaction, although, once chemical process is constituted, it becomes part of the fabric of nature in which these more rudimentary physical realities proceed.

In examining the three stages of physical total individuality , it is important to investigate to what degree the relation of the different processes confirms the order of structural constitution in which they developed.

Taking chemistry as a case in point, one can ask what physical processes provide the prerequisites of chemical interaction. Inertial mechanics and gravity may apply to chemical materials, but mechanics is insufficient to differentiate chemicals, whose specific character depends on qualitative physical differences, rather than the relations of undifferentiated matter in motion. Moreover, physical differences of density , cohesion , and elasticity do not of themselves provide the bases for chemical identity and the affinities of chemical interaction. Similarly, the chemistry of bodies does not itself arise from the physical qualities that differentiate how materials transmit sound , light, and heat .

What is commonly invoked in contemporary times as the basis for chemical identity and possible chemical interactions is the Periodic Table , whose physical individuation of "elements" determines their chemical character and potential chemical relationships. Admittedly, the understanding of the categorizations of the Periodic Table has undergone its own transformations. Nonetheless, what has ultimately anchored the listings of elements is an account of the different atomic compositions of the individual elements. This has rested upon recognition of atoms being composed of, on the one hand, a nucleus containing positive and neutral particles (protons and neutrons , respectively), and on the other hand, electron shells containing negatively charged electron particles, equal in number to the nuclear protons, but distributed in different

“shells” of distinct discontinuous energy levels. The distribution of electrons in these electron shells is what is understood to allow for chemical interactions, where atoms exchange electrons in different ways and thereby combine into molecules or break apart from molecular entanglements. Each atom will thereby have a distinct chemical character in virtue of how many electrons it possesses and what energy levels they have.

Any such account of atomic structure and its chemical implications depends upon the polar charge differentiation of electromagnetism and the existence of physical entities that have a positive, negative, or neutral charge. As matter, each such entity my fill space by involving attractive and repulsive force fields, but in addition to these coeval forces, the components of atomic structure will have a character in respect to the polarity of negative and positive forces, where some will be exclusively negative, others will be exclusively positive, and others will be “electrically” neutral. Each atom as a whole may have a stable neutral charge due to the equal numbers protons and electrons, but its chemical character depends preeminently upon its electron shells.

Atomic structure, and the electrical polarity it incorporates, is not just of chemical significance. The atomic fusion enabling stars to emit light and heat presupposes the electromagnetic character of the particles comprising the atomic nucleus , as well as the convertibility of mass and energy . The states of matter also reflect how atomic structure enables atoms of the same element, as well as molecular materials connecting different types of atoms, to have under different temperature and pressure conditions the features that distinguish solids, liquids, gases, and plasmas. The same can be said of what allows physical materials to have different densities, cohesions, and elasticities. All such physical qualities can be linked to what the electromagnetic polarities of atoms and molecules make possible. To the extent that this is true, physics must preface its development of these physical processes with an account of what might be considered the most minimal physical distinction—that between negatively and positively charged matter. This distinction is absent from pure mechanics, which considers undifferentiated matter. The polarity of electromagnetic charge, however, is presupposed by quantum mechanics as well as special and general relativity , at least insofar as light is electromagnetic radiation.

10.3 Polar Charge and Electricity

What exactly is this minimal physical differentiation of electric charge that enables nature to develop beyond the mechanics of undifferentiated matter in motion? Charged matter, unlike matter per se, exhibits the polar opposition whereby like charges repel and opposite charges attract. Whereas material extension contains simultaneously opposite forces of attraction and repulsion, charged matter adds to this internal opposition an external polarity where a body as a whole exerts attractive or repulsive force upon another body as whole depending upon their respective charges. These electric charges do not depend upon contact but operate at a distance, across which their electric fields emanate. In so doing, they presuppose the boundaries of extension that bodies possess in virtue of their own internal attractive and repulsive force. In addition, these electric charges operate in conjunction with gravity , which exerts its own attractive force irrespective of the charge of the bodies involved. This basic determination of charge polarity does not yet explain the phenomena of electricity and magnetism , but it obviously provides the key ingredient for their constitution.

Whereas matter as undifferentiated may provide for all the mechanics of inertial motion and gravity , as they are determined independently of electromagnetic fields , once matter obtains the minimal physical differentiation of polar charge, a fundamentally new enrichment of natural processes arises. Kantian pure mechanics and the Newtonian classical physics it underpins cannot begin to address this new terrain and the difficulties classical physics encountered in addressing light and other electromagnetic phenomena gave the impetus for quantum mechanics and Einstein’s theories of special and general relativity to accommodate the enlarged physical reality that nature obtains once matter has polar charge.

It bears reiterating how elementary a physical qualification polar charge is. All it minimally involves is a differentiation of matter into polar opposites distinguished simply in that opposites attract, whereas likes repel. In this respect, what is characterized as negative or positive is completely arbitrary, since negative in relation to positive is no different from positive in relation to negative. It makes no difference whether all negative charges are called positive and all positive charges are called negative. So long as their binary opposition is retained, the relationship is the same. Each is simply the opposite of its corollary, attracting it and repelling its like.

Hegel does not explicitly acknowledge the polar differentiation of physical substance when he begins his account of physics with light and stellar emission. Can light and stellar emission be and be conceived without the distinction of physical polarity ? Light in and of itself may not have a determinate charge as either wave or particle, but its origination from and illumination of other bodies involves manifold relations to electromagnetic charge. The photoelectric effect is one obvious example where light impacts upon matter composed of charged particles, causing the movement of electrons. All the various aspects of light reflection , refraction , color , and heating can be connected to the way in which physical substance, composed of polar charged components, takes on a structure that impacts upon these processes. Chemical reactions that generate heat and light obviously depend upon the polar charges of elements and their resulting interactions. Finally, the nuclear fusion by which stars emit light and heat involves the transformation of charged particles into energy .

Kant may maintain that we cannot know anything of necessity about chemistry, but if physical polarity is comprehended in connection with atomic and molecular structure,

mechanism loses its hold as the only domain of nature about which knowledge can be synthetic and a priori.

10.4 Magnetism

Magnetism , which Hegel turns to in connection with the particularization of shape , is explicitly polar in character. As Hegel acknowledges, magnetism involves a process proceeding from the polarization of physical materials. Given the minimal qualitative opposition of “north” and “south” poles, magnetic materials have a simple physical character. One end has a magnetic charge opposite that of the other end, whereby parts of the same magnetic charge repel one another, whereas parts of opposing magnetic charge attract. The magnetic relationship is here expressed in moving forces of repulsion and attraction that are distributed exclusively to different ends of a magnetic object in relation to the like or opposing magnetic charges of parts of other magnetic objects. The dynamic constitution of matter from repulsion and attraction is different insofar as a material body , as occupying space, contains both repulsion and attraction just like any other extended thing. Likewise, the gravitational attraction wielded by any mass is distinct from magnetism since it lacks the polar opposition whereby only opposites attract and only likes repel.

Magnetic bodies contain an opposition within themselves that manifests itself only in relation to other bodies that are equally polarized. This is made manifest through the moving forces of attraction or repulsion that connect unlike and likes, respectively. Whereas gravity attracts bodies insofar as both have mass , magnetism attracts bodies insofar as they or their respective poles have opposing magnetic charges.

What magnetically attracts are thus not identical entities, but opposing poles of physical substances that either already have magnetic poles or have opposing charges induced in them through their interaction with another magnetic substance. Insofar as opposite poles attract and like poles repel, each opposing pole operates in an identical fashion as its counterpart. The only way to distinguish them is that what one opposing pole attracts and repels is the opposite of what its opposing pole attracts and repels. There is no other physical feature that magnetically distinguishes them. Moreover, their magnetic character is exhibited in nothing other than the way in which they manifest their attractive and repelling force in interaction with other magnetic materials.

Although only certain physical objects appear to be magnetic, Hegel points out that, in a certain respect, the polar dimension of magnetism is inherent in physical matter. [6] This generality is expressed in the reach of electrical and chemical phenomena, which magnetism underlies. Electricity and chemical processes each give a more concrete development to the polar opposition of magnetic charge.

Although Hegel does not immediately identify magnetism and electricity, modern physics encompasses both under the heading of electromagnetism . Magnetic fields and the transfer of electrons between atoms in electricity are directly connected, insofar as magnetic fields induce the flow of electrons, just as that flow generates a magnetic field. Clearly, both magnetism and electricity involve the polarity of positive and negative charge. So does chemistry insofar as molecules are generated and broken apart in function of the energy levels and distribution of electrons in their respective atomic electron shells.

Hegel nonetheless distinguishes magnetism from electricity by pointing out that magnetism always involves magnetic poles that are in physical relation to one another, mediated by a point of indifference between them. As any magnet exhibits, the negative and positive magnetic poles are materially connected and any physical division of the magnet produces separate magnets

with the same physical relationship of poles occupying opposing ends of the same material in which at some physical point their respective magnetic fields counterbalance one another. In other words, in a magnet , the opposing poles belong to the same object. Indeed, no matter how the magnet is divided, so long as the material retains its physical identity, each separate fragment retains two opposite poles. In electricity, by contrast, the opposing charges can have an independent existence, where a whole separate entity can retain a solely negative or solely positive charge. This can be seen both in electrostatically charged objects, which are either positive or negative as a whole, and in the positive and negative poles of an electric circuit, between which electricity flows.

Although electrical relationships involve independently realized opposing charges, between which electrical discharges may occur, these do not otherwise alter the character of the electrically interacting physical objects. Electric charges (electrons) may flow from one material to another, but each retains its defining physical nature . In chemical processes, electric charge plays a constitutive role, as evident in how the distribution of electrons in electron shells of different energy levels underlies what reactions can occur between different physical materials. Chemical reactions, however, do alter the physical character of the interacting materials, breaking down molecules into elements or other molecules, or alternately combining elements and molecules into new combinations.

Hegel does not immediately address how magnetism gives rise to electricity and chemical process. Instead he introduces magnetism as the bridge between the immediate, indeterminate shape of physical substance, whose inner formlessness is presented after heat has wrought its “real” idealization upon the determinate density , cohesion , and elasticity of the heated object. When Hegel introduces “shape ” as the initial, most rudimentary immanent physical individuality of material, he identifies it as an immediate form, which being not yet further qualified, that is, mediated, is a shape consisting in a distinct material shapelessness. This shapelessness involves the absence of being determined by something else in a particular way. It is the material’s own distinct formlessness.

The resulting inner formlessness is nonetheless determined in two opposing ways. On the one hand, the shapelessness resides in a brittleness or granulation whereby the material exists as a powder, whose individual minute pieces do not organize themselves in any further determinate way. Shapelessness here consist in the indifferent aggregation of bits of material. On the other hand, there is the opposite spherical form of fluidity, where material has no determinate inner structure but has a continuous agglomeration into a whole, which itself has no further defined configuration than the simplicity of a blob. This undifferentiated blob takes on a spherical shape insofar as the material is subject to external forces to which it responds in a completely uniform way. Hegel points to air pressure as an example of such an external force, [7] which presupposes gravity , and bounds the internally undifferentiated material, which resists in a uniform way.

10.5 Magnetism and Crystal Formation

Hegel introduces magnetism as a physical process that will enable material to develop beyond its inner shapelessness and develop the geometrically determinate organization constitutive of crystal formation. Magnetism provides the bridge from shapeless material to crystallization by being none other than the formative principle of physical material.

At first glance, Hegel's positioning of magnetism as a universal formative principle might seem strange. After all, magnets are particular objects and not every physical material is magnetic in the way in which magnets are. If, however, magnetism is the most elementary realization of electromagnetic polarization, the polar opposition it offers can play a very central role in the further constitution of physical reality.

Significantly, what Hegel turns to as the first formative product of magnetic polarity is not a process of chemical transformation, but rather crystal formation, where material does not alter its chemical identity, but obtains a determinate internal physical organization. Crystallization is not a process where different elements get combined into new types of material, but rather a way in which physical material acquires a geometric internal structure.

Crystal formation generates a very simple, minimal internal structure. It involves a linear organization, determined by the simple geometry of figures composed of straight lines, with no curvilinear complexities. The binary polarity of magnetism lends itself to attractive and repulsive forces that lend themselves to simple constructions where positive and negative poles fit together in linear successions that can easily be replicated in interlocking proliferations according to the same scheme. Hegel can thus speak of magnetism as a becoming of determinate shape , drawing otherwise granular or fluid material into simple geometric patterns. To achieve crystallization , the immediate shapeless material need only be subject to the polarizing forces of magnetism , rearranging the positive and negative elements within that material in the linear simplicity of some geometric function. Thereby magnetism can allow granular material to group together in determinate solid patterns and allow continuous liquid to precipitate into a geometric lattice. Insofar as different materials may have different numbers and distributions of negative and positive charges, their crystallization may take distinct forms, giving each an individual configuration.

Hegel characterizes the crystal as real magnetism , magnetism that has been realized in physical configuration. [8] By contrast, Hegel points out that magnetism itself can only be grasped in an ideal way. Magnetism cannot be directly sensuously manifest. [9] There is no way to examine a magnet by itself and, in virtue of its visual impression, tactile feel, sound , taste , or smell perceive its magnetic polarity . To perceive the poles of a magnet , one must observe how they exert moving forces on other physical objects and perceive how those moving forces are distinct from inertial and gravitational forces. A crystal , however, has an independent shape that immediately reveals the workings of magnetic polarity in the geometric simplicity of its physical shape .

10.6 Magnetism, Crystallization and the Physical Independence of Shape

Shapelessness, magnetism , and crystallization comprise three developments in the determination of the independent physical structure of material. These developments enable physical reality to have a shape of its own that is due to neither external forces nor chemical transformations. These aspects of physical organization unfold sequentially insofar as they build upon one another.

Following Hegel's ordering, we begin with the two types of immediate, indeterminate shape , which do not of themselves involve opposing magnetic poles, let alone crystal formation. Physical material that is merely granular or possesses an internally formless liquidity have the rudimentary "shapelessness" that has not yet been organized by magnetic polarity . Accordingly, magnetism can be and be conceived on the basis of such formless material, insofar as these modes of "shapelessness" do not yet exhibit an internal structure that itself presupposes magnetic polarity .

Shapeless granular or liquid material, magnets, and crystals all have the antecedently developed physical qualities of density , cohesion , elasticity , sound , and heat conductivity, insofar as these are made manifest through interaction with other material substances (including energy as well as mass). Over and above these conditioned aspects, we here have individuating physical structures that exist independently of external solicitation and relationship to other material objects.

With "shapelessness", magnetism , and crystallization , physical reality takes on specific shapes of its own, none of which are directly determined by mechanical impacts, gravity , or the "meteorological" processes of phase changes of matter. Although crystallization may involve a change in state of matter from liquid to a precipitated solid , the phase change does not in itself determine the geometry of crystal formation. What it is to be a solid as opposed to what it is to be a liquid or a gas does not mandate any independent shape . That a material object is a solid does not determine what specific shape it has.

On Hegel's account the shapelessness of granular and liquid material, the polarity of magnetism , and crystallization exhaust the rudimentary independent form that physical material has, independent of the further processes, such as electricity and chemistry, which can develop on their basis. These independent shapes of physical material themselves involve a relative material liberation from the conditioned qualities exhibited in interaction with other things. Namely, heat , with its "real ideality", broke down the fixed determinations of density , cohesion , elasticity , sound reverberation, and heat conductivity itself, setting matter free to take on a shapelessness of its own, from which magnetism and then crystallization can proceed. The crystal comprises the culmination of this development. Crystal formation produces what Hegel identifies as a "free form" [10] insofar as it generates a physical configuration that is not the outcome of mechanical interaction, the reverberation of sound or the mere transfer of heat .

One might imagine that the free form of the crystal is a very peripheral type of physical organization. Many physical scientists, however, would grant that most solid material involves crystal configuration. With the exception of shapeless material, solids tend to have some geometrically determined interlocking composition, whose elements have the linear determination of crystals.

Crystal organization involves a type of material homogeneity insofar as crystallized material

is exhaustively composed of parts with the same geometric structure. Moreover, as Hegel notes, the shape of each such part reflects the shape of the whole. [11] This relation of crystal part to whole is distinctly different from how the organs of an organism relate to the organism in its entirety. Crystals can have different shapes given the possibilities of geometric linear construction, embodying the different ways in which planes can be put together. Whatever shape the crystal may have, its form penetrates the entirety of the material insofar as that material is constructed out of the way in which similar crystals fit together. In this respect, a crystallized material has a form determined by its own internal configuration, as opposed to having a shape due to collision with other objects or some other external process. The crystal has an essential homogeneity, unlike an organism , whose organs have specific differences in configuration and activity owing to the complementary functions they must perform in order to sustain the whole organism to which they belong. The homogeneity of the elements of crystallized material, however, is not that of a heap of grains. Whereas a heap of bits has an aggregate shape undetermined by that of its constituents, crystallized material has a configuration specifically determined by the geometry of its interlocking crystal components.

Although Hegel suggests that crystallized material has a fractal organization, where the shape of the whole is replicated in every part, [12] he does acknowledge that the outer shape of some crystallized material is different from the internal shape of its constituent crystal components. What determines this difference is how the geometry of the constituent crystals allow them to be fitted together, which may sometimes produce a whole that replicates the shape of the individual crystal component, but at other times generates a material body lacking fractal unity. In all cases, the shape of the whole is determined by the geometric design of its crystal components, which in this way produce an internally specific total shape .

It is important to examine why it is that the formative principle of magnetic polarity engenders a geometrically determined crystal organization fundamentally distinct from the internally purposive composition of a living organism . Hegel points out that the planar simplicity of crystallized material is something specific to the shaping of physical matter as physical matter, rather than as something alive. [13]

The fundamental difference between crystal organization and organic unity might seem challenged by the process of crystal formation. After all, crystals “grow” and their growth might seem to be analogous to the growth process of living things. Crystals grow, significantly enough, from a combination of some granular “seed” and a liquid out of which the grain appears to replicate itself. The crystal “seed” could be said to be its own principle of organization. Not only does it generate an increasing whole composed out of that seed’s replication and fitting together, but the ensuing crystal formation does not depend upon any external artificer. The crystal develops and grows simply by being in contact with the appropriate liquid out of which it continues to precipitate and build itself. How is this different from the formation of an organism and the way in which the living thing grows? Answering this question is crucial to understanding the difference between inorganic physical process and life. Indeed, life cannot be understood unless one can comprehend the distinction between the “growth” of a crystal and what it means for an organism to grow and develop. Admittedly, like a crystal , an organism determines its own form, without relying upon an external artificer. The original organism may arise from the contingent assemblage of giant molecules that together interact so as to produce the starting points of their own interaction, as well as a permeable enclosure, allowing the right ingredients to enter and make contact so as to participate in a self-renewing process. On this minimal basis, the rudimentary organism can obtain from its biosphere the appropriate materials and energy its

self-renewing process depends upon. The organism can then grow and, with contingent modifications, reproduce itself, generating from its own living material other organisms of the same type, be it asexually or sexually. In all of these developments, however, the living thing does not take the geometrically simple shape of a crystal and grow by simply adding on additional “cells” of the same geometry to form a whole whose own design is dictated by how the flat surfaces of these crystal cells fit together. Instead, the living thing sustains not a stability of geometric form, but a stability of function and process, where different organs perform complementary functions so as to maintain the life activity of the organism , both in its metabolism with its environment and in the reproduction of its species . [14]

To understand why this discrepancy of crystal and organic composition is not arbitrary, one must attend to how the crystal and crystal formation is determined as an outcome of the magnetic process. As Hegel notes, no matter what specific geometry a crystal may have, it is a quiescent individual totality. The crystal may contain the principle of its own organization and exhibit this in its further “growth”. Nonetheless, besides accruing more units that adhere to one another, the crystal is devoid of any activity, be it internal or external. The different units of the crystalline material do not perform any function with respect to one another or their environment. By contrast, the organs of a living thing exist by engaging in complementary activities that sustain one another and the whole to which they belong, as well as allow the organism to sustain itself in its metabolic activity with its environment. Accordingly, the organs cannot be alike in shape or function, nor can the growing organism just accrete homogeneous additions. Magnetism may have the tension of polar electromagnetic charge, but the crystal forms by resolving this binary tension in joining opposites together into a quiescent geometric fixity, which crystal growth never alters.

Whatever movement polar magnetism generates is linear and not determinative of complementary functions building a self-renewing whole. The crystal grows not by sustaining itself but by adding on external duplicates that fit together, without otherwise doing anything to one another.

Magnetism does transmit itself to the extent that a magnet can make another object magnetic. Hegel does not explore what must be true about a material for it to be magnetizable, lacking any observations of how, perhaps, the electron spins and pathways of certain materials may be lined up by magnetic forces and generate a new magnetic field of their own. Hegel does acknowledge, however, that some materials are by nature magnetic, such as a lodestone, that others become magnetic only when attached to a magnet, that others may remain magnetized when separated from a magnet , and that others appear indifferent to magnetic polarity . Accordingly, Hegel recognizes that there must be physical difference that determine these different ways in which materials behave with regard to magnetic fields. As Hegel points out, the magnetism of an object can be altered by hammering or heating it. The question is, what do these processes affect that undercuts magnetic polarity ? Since hammering and heat alter the internal composition of a material, it would seem that magnetism must be associated with the internal arrangement of the components of physical material. Since what is at stake is magnetic polarity , the arrangement in question must bear upon that of charged constituents of a material.

The basic phenomena of electromagnetism shed light on what may be involved. When an electric current goes around a magnetizable rod, a magnetic field will be produced perpendicular to the direction of the current, with opposite poles at either end of that entity. The resulting electromagnet will lose its charge when the electric current is turned off. Although an independently magnetic material, like a lodestone, need not have an electric current coursing

through it, one can follow current understandings of magnetism and root its magnetic polarity in the orientation of the spin of the electrons of the atoms of which it consists. On this account, a material will be nonmagnetic when the orientation, the spin of its electrons, is fairly random so that there is no overall polarization. If the influence of a magnet can coherently orient the electron spins of such a material, then that material can acquire a magnetic polarity . So long as the electrical charges within a material can obtain a relatively unitary direction, they will engender a magnetic field emanating perpendicular to their coordinated motion. One can thus understand how a material's magnetism will be diminished by any physical processes, such as hammering or heating, that disrupt such coordinated orientation.

The way in which an object's magnetism is affected by its internal organization is indicative of how magnetic polarity can conversely determine the "shape " of a physical material so long as that material has constituents with positive or negative charges. In this manner magnetism can be a formative principle for giving "shapeless" material a configuration structured by the polarity of electromagnetic forces.

The moment magnetism , or electromagnetism in general, endows physical material with charged particles, nature becomes subject to the play of new polar forces of the attraction of like and unlike and the repulsion of like and like. Supplementing inertial force and gravity , magnetic polarity now enables physical material to acquire shapes and processes that are otherwise unrealizable.

Given the minimal character of polar magnetism , the initial transformation of nature has a rudimentary character. The opposing magnetic forces express themselves simply in a linear attraction and repulsion, whose vectors allow planar surfaces to connect along their edges and form geometric linear solids. The linear repulsion and attraction of magnetic polarity thus brings otherwise shapeless material to become organized along the lines of these polar forces.

In this way, magnetic polarity will be the physical basis for material having an organized shape . This organized shape will have a simplified geometric planar character because the magnetic principle of organization has but two principles: that likes repel and unlikes attract. Together, these principles provide the formative engine of crystallization , where planar solid elements interlock into a larger whole owing to the magnetic polarity of their material. To the extent that a physical material is imbued with magnetic polarity , it will structure itself accordingly, independently of other factors. This formation will occur without impediment insofar as the material in question is itself otherwise shapeless, taking either granular or liquid form. The particular type of cohesion and elasticity of such "shapeless" materials provides a relatively tabula rasa for crystallization . Other types of cohesion and elasticity might impact upon crystallization if they impede the planar solid organization of crystals. Shapeless material will lack such restraints and be amenable to becoming organized in terms of magnetic polarity with minimal resistance.

Given the general principle of crystal formation, it is still undetermined precisely how the polar constituents get interlocked. There can be different varieties of crystals, whose elements have different configurations reflecting the different atomic electromagnetic constitution of the physical elements out of which they are composed. These elements have force fields of a particular shape permitting specific forms of material organization, as well as specific types of chemical interactions. On this basis, physical substances can be structured in ways that go beyond the results of inertial and gravitational forces that pertain to matter as such, but do not yet involve chemical, let alone, organic organization. As Hegel notes, nature here structures itself as if there were a geometrician at work, engaging in a purposive engineering of material. [15]

Nonetheless, crystallization does not need any divine or mortal engineer to arise. All that is required is the formative principle of magnetic polarity and the availability of “shapeless” material.

This remains true even in respect to the indeterminacies of quantum mechanics . Heisenberg observes that the process of crystal formation may be based upon atomic structure and the symmetries latent in the solution from which crystals precipitate, but there remains a statistical probability that cannot be eliminated. Quantum mechanics does not allow the shape of the crystal to be determined with any necessity even when the state of the liquid from which it precipitates is completely known. All that can be said is that “the formation of regular shapes is just far more probable than that of a shapeless lump”, for “the ultimate shape owes its genesis partly to an element of chance which in principle cannot be analyzed further.” [16] Nonetheless, that a specific crystal has a certain probability of emerging is determined by the electromagnetic composition and shaping of the material from which it precipitates.

It is important to keep in mind that the configuration of physical shape through magnetic polarity operates solely in respect to spatial configuration and the arrangement of electromagnetic charges. No other qualitative feature or activity enters into this process.

10.7 Shape in Relation to Physical Processes

Once magnetic polarity has enabled physical material to obtain a determinate independent shape , physical processes become qualified by how such shape affects the way a material object relates to them. Hegel turns to examine these physical ramifications in respect to how the independent shape of physical substances mediates their interaction with light and with phase transitions of matter that impact upon taste and odor . The latter processes are described by Hegel as involving "elements of difference." [17] The independent shape of physical material impacts upon taste insofar as it affects the solubility of solidified shape , whereby it transforms into a liquid . Shape impacts upon odor insofar as it affects the vaporization of material, that is, its transition into a gaseous state.

10.8 The Relation of Shape to Light

The relationship of physical shape to light comes first, reflecting how light, or more generally, electromagnetic radiation, provides that by which nature transcends the limits of mechanism and acquires a differentiated physical reality. Hegel develops the relationship of physical shape to light in terms of the further particularization of individual bodies. The way in which an individual body relates to light will exhibit additional physical properties, predicated upon physical shape , by which a physical object will distinguish itself from others having different physical compositions. These properties may belong to the material body , but they depend upon a relationship to other physical factors that are associated with the elements, that is, the states of matter.

Here what lies at stake are the ways in which physical materials, having acquired a form of their own, take on features in relation to physical processes by which physical bodies are differentiated. These particularizations of physical bodies occur because of the physical shape they have and how they relate to the phase transformations of the “elements”.

Hegel connects the relation to light with the relation to the “elements”, raising the question of how and why these relations go together. Why would it be that the independent shape of physical material, resting upon magnetic polarity , should bear upon how it relates to light as well as how it undergoes the transformations from one state of matter to another?

Hegel develops these relationships in sequence, starting with the physical properties emerging from the relation of a physical body to light. This relationship incorporates the more rudimentary relationship built into the illumination of light: the distinction between self-illuminating matter and dark matter. Light emission illuminates what is other than its source by enabling otherwise dark matter to exhibit itself in a relatively theoretical or ideal manner, insofar as its illumination does not appreciably transform itself.

Admittedly, quantum theory suggests that the illumination of electrons requires electromagnetic radiation with a wavelength small enough to achieve the required resolution, and that this requires radiation with a correspondingly high energy level that will deflect the electron that it falls upon, given the tiny mass of the electron . This very real alteration is, however, virtually absent when light illuminates material bodies on a non-atomic scale, for then the energy level of the light leaves the body ’s composition otherwise unscathed.

The illumination of light depends upon matter, be it light emitting or dark. In neither case does light illumination transform the state of the matter in question, unless the intensity is so great that the energy level of the electromagnetic radiation alters the kinetic energy of the components of matter. With matter obtaining a physical composition, based upon electromagnetic polarity , the illumination by light now involves more than the distinction of self-illuminating and dark matter. The mechanics of matter in motion did provide for spatial determinations of matter in general, just as did the rudimentary physical features of density , cohesion , and elasticity . Accordingly, Hegel could point to how the diffusion of light entailed different reflections, due to the geometry of the bodies it illuminated. The more uniform the surface the more light would be reflected. In this consideration all that mattered was the geometry of the surface of a body , not its physical composition.

Now the transmission of light is mediated by the way in which physical material has itself come to be differentiated. This allows light itself to exhibit physical features that otherwise cannot be made manifest. Prominent among these are opacity , translucency , transparency ,

refraction , and color , and the task at hand is to understand how the physical composition of material is connected to these features. Hegel points out that if we just deal with what pertains to matter in general, nothing is available to determine whether matter is going to be transparent, translucent, or colored. [18] With bodies having physical shape , more can be specified.

Already at hand is the contrast of light and dark, as well as reflection and its relation to the geometry of the surface of an object. The light process now becomes further determined with respect to the physical individuality of material bodies. These additional physical features are developed by Hegel in a specific order and we need to examine to what degree this order is a genuine order of physical constitution.

The first topic that is considered is transparency and how it arises through the relation of light to a particular physical composition. Why is some physical material transparent, whereas other material is translucent or opaque?

Hegel points to typical examples of transparent physical material: air, water, and crystals. [19] If air and water were taken as elements, namely states of matter , it might seem that gases, liquids, and crystallized solids are all transparent. Air and water, however, are a particular gas and liquid , just as a crystal is a particular type of solid . Certainly there are gases, liquids, and solids that are translucent or opaque. There appears to be no necessary connection between states of matter and transparency . It is no accident that the differentiation of states of matter did not lead to any corresponding differentiation of relations to light. What then allows a particular gas , liquid , or solid to be transparent?

Hegel remarks that gases and liquids that are transparent have a certain type of homogeneity. [20] This homogeneity does not consist simply in a uniform density , but involves a type of cohesion that accommodates a homogeneous distribution of material. Gases and liquids lack the type of cohesion that would obstruct their homogeneity. Is this true of all gases and liquids, and if so, why, then, are some gases and liquids translucent or opaque?

It is tempting to connect the transparency of crystals to the homogeneity of their composition, whose geometric lattice work replicates itself throughout a crystallized material in a uniform manner. One still must ask, what is the connection between homogeneity and transmissibility of light? Could something be homogenous and yet be opaque? Are there not crystals that are opaque just as are liquids like mercury? Or are all non-transparent gases, liquids, and crystals occluded by suspended particles that interrupt their material continuity?

When Hegel draws upon physical homogeneity as a condition for the transmission of light through material bodies he is taking a feature that is common to the geometric shape of crystals and the shapelessness of liquids and gases. The respective shapes that comprise their material homogeneities are subject to disruption through changes in temperature that, on the one hand, melt and vaporize crystal solids, and, on the other hand, condense gas into droplets of liquid and then freeze these into solids. In any event, material homogeneity might be tied to transparency if heterogeneous composition blocks light transmission by obstructing pathways that a regular, uniform structure might contain. The obstructions in question could affect light transmission whether or not it be or be thought of as a stream of photons or an electromagnetic wave. Irregular organization could deflect light particles and produce irregular interference patterns of waves.

The manifestation of light transmission requires the presence of matter that gets illuminated. The illumination of matter depends upon that matter reflecting at least some of the light that reaches it. In order for a transparent material to exhibit its transparency , the light that passes through it with negligible reflection must fall upon something else that does reflect light, which is then visible through the transparent material. As Aristotle observed, one cannot see anything

wholly transparent except with regard to what shows through it, which can be illuminated only if it is not completely transparent. [21] Even a self-illuminating body would not be visible if it were transparent. The sun , which, to paraphrase Socrates in the *Republic*, makes sight see and the visible perceivable by sight, is itself visible only insofar as it reflects the light it emits. [22]

Nonetheless, transparency is a physical property that a material substance has in its relation to light and this property has some connection to that material's composition. If physical homogeneity is tied to transparency , then the transmission of light through transparent material will be manifest only by illuminating something that is not comparably homogeneous. Otherwise, nothing can be seen through the transparent material so as to reveal the latter's transparency .

Transparency as such does not involve color . Transparency merely pertains to light passing through a material, which transmits light in a purely passive manner, allowing something non-transparent to be illuminated through it without alteration of the light thereby reflected. Whether the reflected light has any particular color is not itself determined by the relation to light of a transparent material.

Similarly, transparency does not in and of itself involve refraction of the light it transmits. Refraction will depend upon further aspects of the geometry and composition of the transparent material as it relates to the direction of the light that passes through it. Refraction for its part does not entail any necessary relation to the color of the light it transmits, unless one is dealing with prismatic material that splits light into a spectrum of colors.

These considerations of how transparency and refraction can be and be conceived without color , support an order of development where transparency and refraction precede color . Moreover, insofar as refraction involves light passing through a material that bends light, the transparency of the refracting material is a precondition for refraction . Accordingly, transparency comes prior to refraction in the being and conception of physical nature .

Furthermore, refraction is able to generate colors insofar as a refracting material bends light in function of its frequency and wave length. If the refracted light has just one frequency and wavelength, refraction will not produce differentiated colors. If, however, "uncolored" light contains different frequencies and wave lengths, refraction enables these to become manifest as different colors. Hence, refraction precedes the differentiation of color .

Admittedly color can also be produced by a translucent or opaque material transmitting or absorbing light of certain frequencies and wave lengths, while reflecting light of other frequencies and wave lengths. This will depend upon certain physical qualities of the material in question, which will thereby give that material a determinate color . One can understand how the different structural geometry and electromagnetic composition of a material will affect what wave lengths pass through, get absorbed, or reflected. Since translucency and opacity are determinable in reference to transparency , their physical constitution is prior to the being and conception of the color differentiation they support.

10.9 Shape in Relation to Transparency , Refraction , and Color

Let us revisit the question of why crystals and liquids might be transparent in virtue of the distinctive homogeneity of their physical composition. One might be tempted to consider the role of physical homogeneity in transparency as connected to the initial discussion of how the undifferentiated flatness of a surface allows it to reflect light, whereas an irregular surface either scatters or absorbs much of the light that falls upon it. Certainly if a material is homogenous it may be expected to have a surface that would also be relatively undifferentiated. Nonetheless, there are fundamental differences in how the homogeneity of a liquid , gas , or crystal relates to surface reflection .

The surface of a liquid will differ from that of a crystal , whose planes have vertices where one surface connects to another in the crystal latticework, producing the diffractions with which jewels sparkle. Although the surfaces of a crystal may be flat, they give the crystal a multiplicity of surfaces at different angles, complicating any simple reflection of light. A body of liquid may reflect light, since in terrestrial circumstances gravity may level a liquid , giving it a relatively flat surface. Nonetheless, an irregularly shaped container may give a body of liquid at least some correspondingly irregular surfaces that impede reflection .

A gas , on the other hand, may be homogeneous and offer an undifferentiated surface to whatever flat surface it expands, but light does not get reflected off it as it may off a liquid . Whereas a liquid may retain its volume in whatever container it occupies, a gas does not give itself any comparable boundary, which could reflect light. The formlessness of a gas leaves it without any determinate surface.

Whatever connection there may between homogenous physical composition and surface regularity, reflection and transparency remain distinct physical relationships. One might wonder how the determination of light itself bears upon them, as well as refraction and color . Can reflection , transparency , refraction , and color be understood if light be conceived as a stream of particles? Can they be comprehended if, alternately, light be conceived as a wave? Or must both conceptions be invoked?

Hegel has polemicized both against thinking of light as a wave and thinking about light as a particle . The particle account of light seems to contradict the continuity of illumination, since the dissemination of rays of light leaves gaps of ever increasing size. Alternately, the wave account seems to require either a medium or substance of its own, both of which defy observation. What Hegel does not consider is how light, and electromagnetic radiation in general, could be considered an energy field that can disseminate through empty space as well as physical materials, and potentially have its energy converted into matter and vice versa.

Let us consider these different options and to what extent they make intelligible any relation between physical homogeneity and transparency .

First, if light consists in streams of particles, of photons, one can comprehend how material with a regular array of empty spaces would allow for the light to pass through unimpeded, whereas a heterogeneous, irregular arrangement of empty spaces would block more, if not all of the paths of light particles. One need not have impenetrable atoms to have empty spaces. One can also conceive of the elements of material consisting in energy fields of a determinate extension with relatively empty spaces intervening between them. So long as these energy fields

are distributed in a regular manner, the same consequences would hold for the passage of light particles.

On the other hand, if the dynamic account of matter allows matter to occupy space continuously, without internal voids, the homogeneity of its occupancy would have a similar effect on light transmission. The resistance to the transmission of light would still be uniform and if this resistance were minimal, this would allow for transparency .

What if light is a wave? Would physical homogeneity facilitate transparency ? In this case, transparency would require that the light waves could somehow pass through the material relatively unimpeded. As a wave, light will have a certain wave length and frequency, or, if the light is more differentiated, a plurality of wave lengths and frequencies, all traveling at the same speed. If color be associated with a determinate frequency, light could either be monochromatic or polychromatic, including white light that contains all frequencies. Since transparency involves the unimpeded transmission of light, irrespective of its color composition, the differentiation of color does not enter into its physical process.

Given that light, as a wave, involves wave length and frequency, the difference between transparency , translucency , and opacity will depend upon how physical structure bears upon the absorption, reflection , or free passage of waves, given their wave length and frequency. Whereas transparency and opacity will involve, respectively, the free passage and blockage of light of any wave length and frequency, translucency will involve the free passage of some light frequencies and blockage (reflection) of others. All of these distinctions can be made thanks to the wave conception, whose compatibility with color determination seems to escape the particle account of light. On the wave conception, the physical composition of materials may lead some to be completely opaque and dark or black, On the other extreme, a material might be such as to reflect all light frequencies, appearing to be white. Others might absorb some and reflect others, while letting some frequencies through. Homogenous physical composition could be associated with transparency if the regular arrangement of material constituents allows for an even wave transmission, without the interference patterns that irregular arrangements could generate.

Since Hegel rejects the wave account of light, he does not bring light frequency into the account of transparency , refraction , or color . Since Hegel also rejects the particle account of light, he has little to offer in clarifying how physical homogeneity can facilitate transparency . He acknowledges that transparency involves a uniform facilitation of light transmission and recognizes that the physical character that makes a material transparent must involve some comparable uniformity that permits unimpeded passage.

Insofar as materials with certain structural homogeneities are not transparent, but translucent or opaque, one must differentiate the types of physical homogeneity that underlie these different relationships to light transmission.

10.10 Refraction and Physical Shape

Refraction is based upon the particular way in which a transparent material transmits light in comparison with other transparent materials. Like transparency , refraction is a physical property that is only exhibited in relation to light. Refraction , however, involves the further relationship between two different physical materials through which light passes. Only when the transmission of light through one material is in physical relation to the transmission of the same light through another material is their respective degree or index of refraction manifest. When reflected light is observed through one transparent material no bending or refraction of light will be noticeable unless it is possible to view the same reflected light through another material with a different degree of refraction and see a divergence in its relative position. In other words, refraction is manifest when light is transmitted through two transparent materials that differ in how much they alter the trajectory of the light that is reflected through them. The light must be reflected by some non-transparent illuminated object, since otherwise the transmitted light will not be visible.

As Hegel notes, all that refraction does is alter the visible location of whatever is illuminated by the transmitted light. [23] This alteration of location varies according to the different degree of refraction that a transparent physical material possesses. Changes in color are not at stake, only changes in the visible place of the reflected objects. Since that change in location may make the reflected object closer or farther away, it may involve a positive or negative magnification. The resulting magnification is, of course, the basis for the optics of microscopes and telescopes.

Hegel connects differences in density with the different refractive character of diverse transparent media. As Hegel points out, density involves a physical spatial determination of how much matter occupies a particular volume, so that one might expect greater density to alter the path of light to a greater degree, all other physical factors being equal. [24] Thus, when light passes through materials of different density , one would expect light to be bent less by more rarefied material. This seems confirmed by how, when one observes an object through air and then water, the object's location is shifted more when observed through the water. Refraction is generally correlated with density and the common contemporary rationale is that the speed at which light travels depends upon the density of the medium through which it passes. In a vacuum light travels at 186,000 miles per second, whereas in water or glass light speed drops down to something on the order of 144,000 miles per second. Such decrease in the speed of light thereby affects the relative position of reflected objects. The change in velocity of light does not in and of itself affect its frequency and wave length. Changes in color are not at issue.

The specific gravity or density of material affects its degree of refraction but not anything else about the behavior of the light that passes through it. Hegel's rejection of the wave account of light thus does not undercut his account of refraction , at least insofar as changes in frequency are not involved.

Let it be granted that refraction rests upon how the density of materials determines how much they slow down the light that passes through them. How then does mass -less light get slowed down by the amount of mass a volume of transparent material contains? If light has no mass and thereby no momentum, light will communicate no moving force to the transparent material that slows it down. Will this violate the law of mechanics of action and reaction? It would, of course, only if changes in the velocity of light had anything to do with changes in momentum. If light, however, has no mass , momentum drops out of consideration. Nonetheless, the different density of transparent materials may still reduce the speed of light by absorbing more of its energy , even

if this energy is not immediately in the form of moving force.

One might wonder how, determined with respect to the densities of transparent materials, refraction has anything to do with physical shape ? Density may not itself constitute an independent shape , but transparency is tied to the specific physical structure of material. Insofar as particular shapes have an inherent connection to transparency , they equally underlie refraction , which only applies to materials that are transparent and, to a lesser degree, translucent.

10.11 Color and Physical Shape

Color does not yet come into play with the constitution and conception of transparency , translucency , and opacity or of refraction . What additional physical relation must intervene for physical material to have a determinate color ? How must light relate to a material object to exhibit color and what aspects of physical shape might enable something to be colored?

Color differentiation may be absent in the contrast between what is self-illuminated and what is dark, in the basic surface geometries of light reflection , and in transparency and in the refraction of light through transparent materials. None of these in and of themselves entail color differentiation.

It is hardly self-evident what provides the basis for color differentiation, let alone what color is itself. Although it is apparent that color is not a matter of the intensity of light, Hegel introduces his account of color by making reference to brightness and darkness. [25] He himself recognizes that simply combining brightness and darkness does not produce color , but only shades of gray. On the other hand, Hegel polemicizes against Newton's theory of light and color , according to which light is composed of different colors: white light and the combination of seven basic colors. [26] Newton's account, however, might seem vindicated by the splitting of light through a prism, whereby white light gets broken into a spectrum of colors. What is happening in this case and what does it tell us about light and color ?

If we consider the role of refraction , we see that the shape of the prism is such that light passing through it will traverse different widths of its transparent material. This might imply that the light will be slowed down to different degrees, according to the different widths of the prism it passes through, leading to different degrees of refraction . What takes place , however, is not just refraction , but the emergence of a spectrum of different colors reflected on whatever non-transparent object reflects the transmitted light.

Contrary to Newton , Hegel maintains that light is not composite, but simple. [27] How then does color arise? Hegel tells us that color involves a relation of light to darkness, but what kind of relation is it, since merely combining light and dark generates only a gray scale? Hegel explains that if two distinctly different brightnesses fall on each other, then we have a qualitative difference of color , rather than the merely quantitative differences that distinguish shadows. [28]

Hegel applies this explanation to prisms, maintaining that the effect of the different widths of the prism shape causes various darkenings of light to overlap, producing different colors. [29] How are these overlaps of brightnesses and darkenings generative of anything more than varying shades of gray? Hegel is at a loss to offer a convincing account of the emergence and being of color , having deprived himself of any wave account of light.

If light has a wave dimension, the physical basis of color becomes more intelligible. One can follow the ordinary contemporary understanding and refer color to the frequency and corresponding wave length of light. The challenge then is to understand how different physical compositions are connected with reflecting certain light frequencies and absorbing or scattering others. The regularity of a surface may make intelligible how light in general is reflected rather than scattered, but it does not itself explain how a physical body can have a determinate color , indicative of a differential reflection of light frequencies. The obvious connection would seem to lie in linking the physical structure of a material with the wave lengths of different colors. Presumably, the material's surface and, in the case of transparent and translucent materials, interior would contain configurations of such dimensions that only light of certain wave lengths

would be able to reflect itself off of them. Needless to say, the shorter the wave length, the smaller the physical structure might be that could reflect the corresponding light frequency. Light visible to the human eye might thus be such as to have a wave length that cannot be reflected by such miniscule structures as an atom or a molecule , preventing these from having any humanly perceivable color . Much larger configurations of physical shape would be relevant bearers of color for human vision.

Associating physical structures with the reflection of certain light frequencies may connect color to particular materials, but it leaves unexplained another aspect of color determination. This is the qualitative differentiation of specific colors, which seems to involve more than the indifferent continuities of quantitative specifications of light frequencies. Whereas the increase and decrease of light frequency and wave length contains no inherent qualitative boundaries, color seems to involve measure relations, where quantitative differences take on qualitative character, distinguishing red from yellow and yellow from blue, and generating complementary relationships between qualitatively different colors. One might regard such qualitative differentiations to be purely nominal, especially since one can see how each distinct color can blend gradually into those that straddle it on the scale of wave lengths. Nonetheless, the physical reality of color remains unimpeached.

10.12 Odor , Taste , and Physical Shape

Whereas early modern philosophers through Kant and their positivist successors are content to regard color , odor , and taste to be “secondary” properties of purely subjective significance, Hegel’s account of physics attempts to show how these properties are objective features of nature that reside in how physical shape enters into relation with real physical processes. We have followed the course of Hegel’s attempt to develop color , and now it is time to address the physics of odor . This is not because the physical configurations that give materials their color are equally determinative of their odor , but because materials may have color without having odor , but not possess odor without having color . The reason for this lies in how odor , like taste is generated.

The relevant contrast can be found in what distinguishes the relatively theoretical character of sight from the more practical character of smell and taste . Whereas sight sees the color of an object without appreciably altering it, nothing can be smelled unless some particles of the object waft off of it and make their way to the sense organs of smell, just as nothing can be tasted unless some part is dissolved so as to make contact with the sensory organs of taste . Odor , like taste , is a physical feature that an object has only insofar as it is subject to an at least partial dissolution. In the case of odor , this dissolution allows parts of the object to be carried by air or some other gas . In the case of taste , this dissolution dissolves parts of the object into some liquid . What distinguishes odors and tastes from one another is the physical configuration of the parts of materials that get disseminated in gas or liquid .

Hegel identifies odor as the particular way in which a physical object relates to air or to gas in general in terms of its own volatilization. [30] Physical materials will have different odors in virtue of how their physical structure differentially determines their volatilizations. This differentiation revolves around two aspects: the ease of volatilization and the structure of the parts of the materials that get volatilized. Both of these aspects of odor will reflect the physical composition of different materials.

Odor thereby constitutes a physical property that has an objective reality of its own, even if there are no animals around to smell it. Odor , like color and taste , exists whether or not it is perceived, as well as whether or not any sentient organisms have evolved anywhere in the universe. The psychology of color vision, smell, and taste may depend upon animal life, but the physical reality of color , odor , and taste does not.

Whether something has odor depends first of all on whether it has a physical composition allowing it to be volatilizable. Metals, for example, are generally devoid of odor , reflecting something in their composition that prevents volatilization, at least so long as they are in a solid state. Given how electromagnetic polarity provides a formative principle for the independent shape of materials, one can look to various arrangements of charged constituents and distinguish those that have the greatest cohesion that would resist the dissolution on which odor , as well as taste depends.

The relevant structural arrangements that affect odor are different from those that determine whether a material is transparent, translucent, or opaque. Transparency , translucency , and opacity can all be accompanied by different degrees of odor , including a complete absence of odor . This should not be surprising since what makes a material transparent, translucent, or opaque concerns how its structure affects the transmission and reflection of light, whereas odor concerns how physical structure affects a material’s volatilizability. The latter pertains to the

material’s dissolution whereas the former pertains to how the material relates to light irrespective of its structural tendency to resist dissolution.

Volatilization has to do with how a material undergoes a phase change, where parts of it become vaporized, wafting along with air or some other gas . In the case of taste , the volatilization has to do with the phase change from solid to liquid , whereby a material gets at least in part dissolved in a liquid . Such phase changes are generally relative to levels of heat and pressure that are sufficient to elicit some material dissolution. Owing to differences in structural cohesion , materials may vaporize only under very distinct conditions of temperature and pressure.

Hegel observes that the vaporization generating odor involves vaporized material becoming part of a gaseous medium, which then may be sensed by animals with a sense of smell. Hegel makes the point that air has no odor insofar as it is a medium of odor . [31] This is why animals can smell what wafts through the air, rather than smelling air itself. Admittedly, one can smell a gas as well as what may be vaporized in it. What makes this possible is that the gas and vaporized materials have different structures that can be separately sensed by sense organs capable of distinguishing their different configurations. Even though air, like any gas , is already in a form whereby it can be received by sense organs, it may well be that those sense organs are either indifferent to its structures or unable to sense them, insofar as it is not air, but what is vaporized within air that pertains to their adaptability to survive. The same considerations apply to taste , since the dissolution of a material in a liquid gives it a determinate taste that can only be sensed in its own right if a sentient organism can distinguish its configuration from that of the liquid in which it is dissolved.

Whereas solids may or may not have an odor or taste depending upon their susceptibility to dissolution, every gas and every liquid would seem to have an odor or a taste respectively. Even if we homo sapiens may not distinguish the smell of air, that does not mean that the determinate physical configuration of air constituents does not constitute a determinate odor , which could be sensed in principle by the appropriately smell sensitive animal. The same consideration applies to the taste of water or any other liquid . Whatever seems to be taste neutral has a determinate configuration of its own that is thereby tasted as neutral and may well be savored as anything but taste neutral by animals with a different sense organ endowment. In every case, the differences in smell and taste reflect the various shapes of gaseous vapor constituents on the one hand and of liquid constituents on the other. To the extent that these different shapes will only fit into sense receptors of a matching configuration, animals will be able to distinguish various odors and tastes.

Differences in density of gases and liquids might affect the intensity of smells and tastes, since the more dense concoctions will involve a higher degree of odors and savors in a given volume of gas or liquid . Variations in density will not, however, affect which odors and tastes are present, unless a gas or liquid is so rarefied that the minute quantity of a material will render its odor or taste imperceptible.

What would lead a terrestrial animal to be indifferent to the smell of air or the taste of water is the ubiquity of them as media in which materials give off their own smells and tastes. Air and water would be experienced as ever present background constants, against which other smells and tastes get distinguished from one another. Accordingly, the smell and taste of air and water would drop out of consideration, since every smell contains the odor of air and every taste contains the taste of water, including alcohol that is ingested with saliva. Air and water would supply the neutral points for comparison of other odors and savors.

Although odors and tastes are related respectively to gaseous and liquid states of matter , they rest upon particular physical configurations that these states of matter can possess, given the electromagnetic constitution of material substances. Each of these various physical shapes will somehow conform to the defining character of gases and liquids, which will not have any physical realization without embodying some such particular configuration. These configurations are those that material can retain when it loses solid form and liquefies or vaporizes. Those changes of state involve neither alterations of chemical bonds of molecules nor alterations of the nuclear structure of atoms. They instead involve changes in kinetic energy of material constituents that lead to nodal changes in how that material coheres. Liquids, as we have seen, obtain a frictionless displaceability without relinquishing their determinate volumes, whereas gases freely expand until restrained by some material container or force field containment.

Accordingly, the process of odor and taste sensation need not involve any chemical, let alone nuclear reaction. Instead, smelling and tasting involves a physical relationship based upon the shape of the vaporized or dissolved materials that make contact with the sense receptors to which they physically correspond. Insofar as magnetic polarity is responsible for giving material a determinate shape , the physical reality of odor and taste , like that of color , is predicated upon the formative physics of electromagnetism .

This grounding in electromagnetism holds generally for all the so-called secondary properties, which early modern philosophers through Kant mistakenly relegate to subjective phenomena, as if physical reality could be devoid of color , odor , taste , or any other qualitative features. Hegel may not deliver sufficient accounts of how these properties are physically determined, but he does properly develop color , odor , and taste as three objective particularizations of individual physical materials. These properties are not mere sense datum, residing in the subjective process of perception. Instead, they are physically independent features that reside inherently within physical materials owing to their shape , even though they become manifest in relation to light and other states of matter.

The physical reality of these features eliminates the problem of “ownership” that plagues Empiricists who struggle to assign sense data to a determinate object. The sense data or sense impressions may well be sensed, but the object to which they may be alleged to belong has no independent sensible “shape ” of its own that can be perceived. Empiricists thereby face the dilemma of having no resource for attributing the sense data to specific objects. The latter have no independent identity and the mere contiguity or coexistence of sense impressions is insufficient to attribute any necessary ownership to some imperceptible thing in itself. To overcome this indifference of sense data to one another and any indeterminate substrate to which they might be referred, Empiricists have had to presume that the thing to which they allegedly belong somehow has the power to keep these sensible qualities together as its own. Experience, however, cannot provide us with an understanding of power or anything else, for as Hume never tires of pointing out, repeated observations of similar associations only confirms their particular occurrences, but not any necessity or universal connection. For this reason, Hume’s appeal to custom as a psychological explanation of our awareness of causality hardly resolves the problem, This is especially true since Hume presupposes a psychological causality whereby repeated observations of similar connections causes the observer to expect such connections in the future and thereby impute causality to those associations. [32]

The physical account of color , odor and taste , by contrast, directly ties these features to the individuating physical composition of the things to which they are attributed. Physical entities have color , odor , and taste because they possess a particular independent shape that determines

how they relate to light and to vaporization and to solubility. There is no “binding” problem of connecting these qualities to the same object. This is because every shaped entity in nature has a determinate color , odor , and taste due to its particular physical configuration, which has an independent physical unity of its own that is open to examination.

If the philosophy of nature were limited to pure mechanics , then indeed we would be compelled to treat these physical features as merely subjective “secondary properties” with no ground in the mechanism of matter in motion to which the universe is reduced. In doing so, however, we would face the dilemma of how to explain the appearance of these subjective phantoms, for which pure mechanics has nothing to offer. Since matter provides no explanation, we might take refuge in some separate substance of mind, to which we attribute awareness of these subjective phantoms. By accepting such mind/matter dualism, however, we would be at a loss to explain how the mechanics of matter can affect an immaterial mind and produce the perception of such “secondary properties”.

Hans Jonas points out that all attempts at reducing everything to mechanism contradict themselves because they point to these phenomena and claim that these phenomena are epiphenomena, that is, illusory. In so doing, these reductionists admit that these appearances are produced by the mechanistic material processes, yet they hold that these appearances have no real efficacy of their own. This contradicts the basic framework of mechanism , wherein every effect of the mechanistic process is just as much a cause of further alterations. Moreover, on the mechanistic account, every effect takes some expenditure of force to produce. These phenomena, however, occur without explanation because they are not real things that require extra force to be produced. The only forces that are in play are those at work in the mechanical relations that have their own action and reaction. The moment one attempts to connect any of the so-called secondary properties to these mechanistic processes, one allows for there to be a process where something produces something at no expense and produces something that has no further causal efficacy. All this violates the basic framework of the mechanistic universe. Consequently, as Jonas observes, the attempt to reduce nature to mere mechanism , while admitting epiphonema, makes no sense. [33]

Notes

1. Hegel, *Philosophy of Nature* , Remark to §304, p. 150.

2. Hegel, *Philosophy of Nature* , Remark to §305, p. 152.

3. Hegel, *Philosophy of Nature* , §306, p. 156.

4. Hegel, *Philosophy of Nature* , §306, p. 156.

5. Hegel, *Philosophy of Nature* , §308–336, pp. 158–272.

6. Hegel, *Philosophy of Nature* , Remark to §312, p. 163; Zusatz to §312, p. 166.

7. Hegel, *Philosophy of Nature* , Zusatz to §311, p. 162.

8. Hegel, *Philosophy of Nature* , Zusatz to §315, p. 175.

9. Hegel, *Philosophy of Nature* , Zusatz to §312, p. 164.

10. Hegel, *Philosophy of Nature* , Zusatz to §315, p. 175.

11. Hegel, *Philosophy of Nature* , Zusatz to §315, p. 177.

12. Hegel, *Philosophy of Nature* , Zusatz to §315, p. 177.

13. Hegel, *Philosophy of Nature* , Zusatz to §315, p. 177.

14. As Heisenberg writes, "the kind of stability that is displayed by the living organism is of a nature somewhat different from the stability of atoms or crystals. It is a stability of process or function rather than a stability of form." See Heisenberg, *Physics and Philosophy*, p. 128.

15. Hegel, *Philosophy of Nature* , Zusatz to §315, p. 175.

16. Heisenberg, Werner , *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper Perennial Modern Classic, 2007), p. 199.

17. Hegel, *Philosophy of Nature* , Zusatz to §316, p. 181; §321–322, pp. 217–219.

18. Hegel, *Philosophy of Nature* , Remark to §317, p. 182.

19. Hegel, *Philosophy of Nature* , Zusatz to §317, p. 184.

20. Hegel, *Philosophy of Nature* , Remark to §317, p. 182.

21. Aristotle , *De Anima (On the Soul)*, Book II, Chap. 7, 418b4–6, in *The Complete Works of Aristotle —Volume One*, p. 666.

22. In the *Republic's* analogy of the Good to the Sun , it is of key important that the Good not only give being to the Forms and to the Reason of knowers, as well as enable those Forms to show themselves in our thought, but also produce a Form of itself and enable knowers to think that form truly. Otherwise, there is no way for thinkers to be certain that reason grasps the truth. See Plato , *The Republic*, Book VI, 508a–509b.

23. Hegel, *Philosophy of Nature* , Remark to §318, p. 186.

24. Hegel, *Philosophy of Nature* , §318, p. 185; Zusatz to §318, p. 190.

25. Hegel, *Philosophy of Nature* , §320, p. 194–195.

26. Hegel, *Philosophy of Nature* , Remark to §320, pp. 198–199.

27. Hegel, *Philosophy of Nature* , Zusatz to §320, p. 201.

28. Hegel, *Philosophy of Nature* , Zusatz to 320, p. 202.

29. Hegel, *Philosophy of Nature* , Zusatz to §320, p. 204.

30. Hegel, *Philosophy of Nature* , §321, p. 217.

31. Hegel, *Philosophy of Nature* , Zusatz to §321, p. 218.

32. Hume, David , *An Inquiry Concerning Human Understanding* (Indianapolis: Bobbs-Merrill, 1955), pp. 67–68.

33. Jonas, *The Phenomenon of Life*, pp. 128–130.

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11. From Electricity to Chemistry

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11.1 Electricity as the Final Form of Total Individuality

The physical process of electricity follows upon the relations of shaped material to light, as well as the physical relationships by which odor and taste are determined. Electricity comes after them in thought and nature insofar as they do not themselves involve electrical phenomena, but are physical determinations possessed by the factors in and through which electricity operates.

Hegel develops electricity in the second part of his presentation of what he calls “the physics of total individuality ”. [1] This second part involves physical processes in which independently shaped material bodies are further particularized, without chemical interaction. The first such particularizations involve relations to light in which materials are physically distinguished by transparency , translucency , and opacity , as well as by different degrees of refraction and varieties of color . These are followed by particularizations involving relations to what Hegel calls the “elements of opposition”, namely air and water, whereby materials manifest odor and taste .

Although Hegel groups electricity as the third and last physical particularization of shaped material, he recognizes that the electrical process is significantly different from both preceding particularizations. Electricity seems dis-analogous to the previous developments in that electricity does not appear to be rooted in the independent shape of the bodies it involves. Like the other physical relationships, electricity does involve the way a physical body is conditioned by something else. Electricity, however, comprises a different type of relationship that seems indifferent to these other physical features and the physical configurations on which they rest.

Those features that involved how a physical material relates to light had an ideal character insofar as the relationship to light left the individual physical body more or less untouched. They simply make themselves manifest in various ways in connection with how light relates to a material’s specific physical composition.

By contrast, in the particularizations involving the “elements of opposition”, there is a physical dissolution. The physical body has to vaporize to some degree to have an odor , just as it has to dissolve in part to manifest a taste . The physical body , however, has to retain a distinguishing structure in those remnants that vaporize or dissolve in order to possess a specific smell or savor.

Electricity is not merely ideal insofar as electrical current transports charged components of the materials between which and through which it passes. In so doing, electricity involves a relation between physical bodies that does in some respect depend upon their composition. The electrical relation pertains to bodies so constituted that they can have opposite aggregate electromagnetic charges that electrical current can discharge, at once, in alternation, or continuously.

Given that atoms be composed of positively charged nuclei and negatively charged electron shells, there seem to be two alternative ways in which materials could have opposing aggregate electromagnetic charges. On the one hand, atoms could undergo changes in their nuclear composition, while leaving their electron shells unaltered. Positively charged particles (i.e. protons) could be added or removed, leaving the atom with a net positive or negative charge. On the other hand, electrons could be added or removed, with the same aggregate results. To change nuclear structure, however, requires vast amounts of energy , with potentially unstable results, all of which would disrupt the opportunity for electrical circuits to be formed. By contrast, the movement of electrons between atoms requires much less energy and involves particles of much

smaller mass , both of which facilitate electrical processes on this basis. Of course, if anti-matter is present or generally prevails, the situation could be reversed with the outer atomic shells having positive charge and the nuclei having a negative charge. In that case, the result would be virtually indistinguishable, since polar charges are merely the opposites of one another and otherwise indistinguishable. Either way, electricity can be understood to involve the passage of charged particles between material bodies of opposite aggregate charge.

Hegel begins his account of electricity by considering static electricity , where an object acquires an aggregate electrical charge through some sort of physical contact that disrupts its original total neutral charge. [2] This disruption need not involve any deformation of the shape of the bodies in question, nor any specific alteration of their physical composition, including what affects how they interact with light or how they have smell or taste . Instead, the contact need only draw off or add electric charges of one type. In our terrestrial case, this would involve removing or adding negatively charged particles, namely electrons. The discharge of the imbalanced aggregate charge would depend upon the body in question coming into sufficiently proximate contact with another oppositely charged body as to facilitate a discharge transferring electrons and reestablishing aggregate charge neutrality on both sides.

In a common example of static electricity, a certain object can be rubbed with a cloth of a certain kind and that physical interaction, which may otherwise generate heat through friction, produces a polar charge differentiation, leaving the rubbed object with an aggregate charge of one kind. If that object is put in proximity with another object with the opposite aggregate charge, and the charge differential is sufficient to overcome the insulation of the air between them, a spark will leap from one to the other, neutralizing the electrical imbalance between them. As Hegel recognizes, the principle of electromagnetic polarity that underlies electricity is the same as what figures in magnetism as well as in chemical process. [3] In all these cases, the opposition of polar charges, for which likes repel and opposites attract, provides for physical processes that go over and beyond what inertial and gravitational force can accomplish.

Although electricity further concretizes magnetic polarity , Hegel points out that electricity has a superficiality that distinguishes it from chemical process. [4] Although both electricity and chemical reactions involve transfers of electrons between atoms, electric current does not alter the chemical composition of the material through which it flows. Molecular bonds remain more or less intact. By contrast, in chemical process, the transfer of electrons from the shell of one atom to that of another joins those atoms together through the attraction of the resulting opposition of aggregate positive and negative charges. Insofar as one or more electrons have moved from one atom to the other, the charge neutrality of each atom , residing in the equal number of electrons and protons, is disrupted. The atom with added electrons acquires a net negative charge and its counterpart acquires a net positive charge, drawing them together through the resulting polar electrical attraction. This attraction of opposite aggregate electromagnetic charges provides the force of the resulting chemical bond , which is much weaker than the bond keeping nuclear particles together. Nonetheless, the chemical electron transfer is sufficient to change the molecular structure of the materials involved. By contrast, electrical current leaves molecular structure unaltered since the passage of electrons from one body to another continually reestablishes electrical neutrality without joining atoms to one another in a new molecular arrangement. Electricity is thus relatively superficial since, as Hegel emphasizes, it leaves intact the physical individuality of the materials it involves. [5] Chemical process will penetrate the physical being of reacting chemicals, altering their physical individuality by transforming their composition. The circuiting of charged particles in electricity will continually maintain atomic

and molecular composition, while adding the magnetic field that the passage of charged particles generates.

Because electricity does not alter the physical composition of the materials through which its charged particles pass, electric discharge and electric current relate materials solely in respect to their capacity to provide displaceable charged particles. This does not involve a relation to a certain state of matter such as gas (as in odor) or liquid (as in taste). Nor does it depend upon a chemical affinity between materials. Even chemically inert materials could be susceptible to electricity, so long as their electrons can be dislodged from their full shells, which then can receive electrons from other materials in return. This indifference does not mean that the materials in electrical transmission have no color , smell, taste , or chemical identity. It just signifies that the process of electricity relates to a different aspect of physical composition, namely the capacity to hold and transmit an aggregate electrical charge.

In these respects, electricity is more concrete than magnetism and more superficial than chemical interaction or chemism. All three physical processes consist in a relationship between material bodies that involves electromagnetic polarity . For these reason, none are reducible to mechanical interactions, nor the more elementary physical relations of states of matter , density , cohesion , and elasticity .

Whereas magnetism involves a polarity internal to an individual body , electricity involves a polar opposition between material bodies with opposing aggregate electromagnetic charges.

These bodies have an electrical tension due to their charge opposition. As Hegel notes, this electrical tension involves a mechanical relationship [6] insofar as the opposed bodies must be kept apart, at least to begin with, whereas the aggregate electrical attraction can cause the opposing bodies to move towards one another, at least until the unbalanced electrical charges get discharged in a spark or continuous current.

We thus have two bodies that fall into an electrical opposition, consisting in the electrical tension of opposing aggregate charges awaiting discharge. For the opposition and its tension to be present, the opposing bodies must be kept apart by some physical barrier, be it a vacuum , a resisting material, or a circuit breaker that allows the polarity to subsist and not be instantaneously dissipated. This involves some resistant moving force, just as the overcoming of the tension depends upon an external impulse to put the bodies in a position where electrical discharge can occur. These mechanical factors may be necessary, but they are not sufficient to determine the ensuing electricity, which depends upon the electromagnetic relationship and whatever physical composition allows it to be maintained. The electrical relationship that ensues does not alter the density , cohesion , elasticity , reverberation, color , smell, or odor of the materials involved unless the resistance to the electrical discharge produces enough heat to affect these other physical features.

What is in play is the electrical polarity that magnetism involves. Although the electrical tension opposes bodies with aggregate opposite charges, these charges are no different than those on the poles of magnets and the electrical discharge that follows generates a magnetic field of its own determined by the direction of the resulting flow of charged particles. Electricity involves an interaction between bodies that alters the aggregate charge they have acquired. There are two sides to the process. One consists of the establishment of the initial electrical tension, producing the difference of aggregate charges or the voltage between them. Then there is the process whereby the charges are neutralized, or, as Hegel says, conducted and redistributed. [7]

Some process must first make the participating bodies loose or gain charged factors so as to acquire opposite aggregate charges. This process is different from that by which material

becomes magnetized. A magnet does not have an aggregate charge, but rather has poles of equal opposing charge, so that the magnet as a whole is electromagnetically neutral. Since polar electric charges are defined by simply repelling their like and attracting their opposites, the objects in electrical tension need not have any other physical difference than their difference in aggregate charge. Like north and south poles, there is nothing to distinguish them other than that one is not the other. Bodies in electrical tension may be composed of the same or different materials provided they have a physical composition allowing them to hold an aggregate charge in the first place .

Moreover, that an electron has a different position in an atom than a proton and a much smaller mass is not intrinsically connected to the opposite charges they possess. This is shown by the composition of anti-matter , which involves a converse atomic structure where the nucleus has a net negative charge and the surrounding particle shells have a positive charge. In either case the same law applies, that likes repel and unlikes attract.

What makes electricity a more concrete physical reality than magnetism is that it (1) involves bodies that contain magnetic polarization within themselves in order to have any determinate shape and the possibility of acquiring more charge of one type than another, and (2) produces a magnetic field when electrical discharge occurs. Internal polarization is the basis for having any aggregate charge since if a material were composed of just one type of charge, it could not cohere unless the repulsion of its like charges was counterbalanced by the gravitational attraction of the body itself. In that case, however, the body would be a featureless sphere, lacking any internal magnetic polarity that could give if a determinate shape and the physical features that follow. Further, one might wonder how any electrical discharge could occur. Consequently, internal polarization is the basis for having any kind of aggregate electrical charge. Unless material has both negative and positive constituents, it can have no physical identity, nor provide the charges that can be redistributed to produce electrical tension. Only when opposite charges are in some sort of stable arrangement, as in the atomic structure of a positive nucleus surrounded by negative electron shells, is a material susceptible to a mechanical interaction that could produce static electricity , as when something is rubbed to produce an aggregate charge, or alternately be susceptible to having charged particles that could be pulled along to circuit through other materials by the electromagnetic force of voltage, that is, of a great difference in polarity .

Although electricity may be superficial in comparison with chemical process, it can be accompanied by other physical alterations. Besides the mechanical manifestations of electric repulsion and attraction, the discharge of static electricity will ordinarily produce light, as so evident in lightning. Hegel recounts various experiments where individuals place different metals in their mouths and then experience various taste and smell sensations when an electric current passes through those metals. [8] Just as the neutralization of electrical tension through discharge produces light in the case of static electricity , so it may affect the dissolution and vaporization of material by overcoming the repulsions and attractions of an aggregately unbalanced charge, as well as by producing ionizations that impact upon sense organs of smell and taste .

11.2 Light and Electricity

The production of light in electrostatic discharge reflects the electromagnetic character of light and the connection between electrical energy and that of light. The same can be said of how chemical reactions can generate light, as well as heat . Since chemical interaction may release energy as bonding forces are set free, it can be no surprise that such electromagnetic energy can find expression in light emission. Of course, the release of the much greater forces of nuclear bonding and the conversion of nuclear matter into energy can generate much more immense light emission thanks to the same connection of light to electromagnetism .

In paragraph 324 of the *Philosophy of Nature* , Hegel points out that the tension between electrically charged bodies does not involve the physical nature of the body in its concrete character, but rather concerns its abstract self as a bearer of polar charge. [9] In relation to light, the physical body exhibits its abstract self-identity, showing its external manifestation without undergoing concrete alteration. In electricity, the charged body is a polar self, a self that is intrinsically related in an oppositional way to another body of the opposing charge. This is an abstract individuality first in that it abstracts *from* all sorts of features that do not themselves enter in the electrical relationship. The electrical identity of the body leaves these other manifold physical attributes of the entity unaltered. The body is simply positive or negative, with a determinate magnitude of aggregate polar charge. Secondly, the electrical individuality of a body will be manifest simply in terms of the electrical tension and discharge in which it participates. This manifestation cannot be reduced to the solitary motion of the charged body , since electricity can only be exhibited by motion with respect to another charged body . Moreover, electricity does not simply involve the repulsion or attraction of the poles of different magnets. The emission of light through a spark and the alterations in taste and smell might offer confirmations, provided other sources than electricity can be ruled out. Similarly chemical alterations will not provide distinctive evidence, unless they depend upon electricity. Interestingly enough, when Hegel begins his development of chemical process he will begin with galvanization, where chemical changes are produced by an electrical current passing through specific chemicals. [10] This gives immediate testimony to how chemical process rests upon the aggregate charge differentials that electricity involves and that chemical bonds bring into the formation of molecules.

Aristotle and Hegel associate heat with light, first and foremost in stellar light emission, and then in the chemical process of combustion. Without introducing the electromagnetic character of light, as well as the convertibility of mass and energy , it is difficult to establish the connection of heat and light. If heat is considered as the real idealization of material, emanating from the reverberations of sound , one might wonder how light either generates heat or is generated by heat . If, contra Hegel, light is understood as a wave, then the reverberations connected to heat might seem associable with light. Complicating any such connection, however, are two factors: first, the massless character of light and the transmission of light waves through empty space. It is far from clear how the kinetic energy of heat could be connected with the energy of light waves, when the former involves material with mass and the latter does not. If, however, energy is convertible with mass , then light can have communicable energy without having to possess any mass of its own.

These considerations are relevant to the connection of electricity and light insofar as the energy of electrical tension and discharge could conceivably be converted into light energy , as

well as heat . Hegel has little to say on this matter, and his account of electricity confines itself to the basic features that distinguish electricity from magnetism and chemical process.

What Hegel does present is the insight that the process of physical development up through electricity provides all that is necessary for chemical relations to come to be in thought and nature .

11.3 How Electricity Provides the Enabling Conditions of Chemical Process

There are two ways of understanding how electricity provides the enabling conditions of chemical process. On the one hand, one can presume that chemical process cannot take place without electricity. This, of course, requires some account of how this is so. On the other hand, one can consider electricity to be the last development of physical process that does not yet involve chemical process in its own constitution. Electricity is the penultimate process in which physical bodies become individuated without yet involving any kind of chemical individuation. These two aspects are sides of the same coin. Insofar as electricity is a precondition for chemistry, it cannot itself depend upon chemical individuation. If electricity did, it would not be prerequisite for chemistry; rather chemistry would be the basis for electricity.

What then is the relationship between electricity and chemical process? As Hegel points out, electricity takes electromagnetic polarity to a new concrete level. [11] Whereas magnetism polarizes material such that a single body contains opposite poles, electricity relates bodies that have aggregate opposite charges, resolving electric tension through electrical discharge from one opposing body to another. Whereas magnetism individuates bodies through an internal polarization, electricity individuates bodies with respect to how they transmit electric charges to one another.

Chemical interaction also involves materials passing or retracting electromagnetic charges to and from one another. Whereas electricity does so without altering the character of the bodies involved, in chemical reaction, materials either join together to form new molecular structures or break apart molecular bonds to form new separate materials. To paraphrase Hegel, electrical relationships are superficial in that they do not alter the composition of bodies, but simply exchange charges between them. By contrast, in chemical relationships, charges, namely electrons, pass from an electron shell of one atom to an electron shell of another, leading to new material compositions. Generally speaking, this involves three basic options. First, atoms may join together into a molecule by one atom receiving an electron from the other, thereby acquiring an aggregate positive charge while its benefactor atom acquires an aggregate negative charge, causing them to bond together. Secondly, the atoms may join together by sharing electrical particles in alternation, so that the aggregate charges alternate, but the attractive force remains their constant bond. [12] Thirdly, such molecular bonds can be broken when the aggregate charges are neutralized by a return of electrons leaving each atom electrically neutral and no longer electromagnetically attracted to its counterpart. In all these cases, the nuclear composition of each atom remains unchanged. What alters with chemical relations is the distribution of electrons in the electron shells of the reacting materials.

If we accept this account of the basics of chemical relations, it is understandable how the electrical transfer of charges can precipitate chemical reactions, both conceptually and in nature . Instead of electrical transfer producing a current that leaves bodies otherwise unchanged, in chemical process, the transfer has a stable result. Formerly electromagnetically neutral material factors (atoms of a determinate electromagnetic structure) bond together or separate through the establishment of an electrical tension and subsequent discharge, involving transfers of electrons from the electron shell of one atom to that of another. Electricity provides the aggregate electromagnetic opposition of materials, as well as the transfer of electrical components that

provide the constituents of molecular bonds. What makes these aspects of electricity chemically relevant is, however, a further differentiation, consisting in the difference in electromagnetic composition of interacting materials.

Magnetic polarity , as internal to material, not only provides the formative principle for the physical individuation of material shape , but also for the individuation of specifically chemical elements . These are individuated by how they contain determinate arrays of positive, neutral, and negative charges in their most rudimentary, atomic structures. These can be considered chemical *atoms* not because they are indestructible, but because they cannot be further broken apart without a material losing its specific chemical identity, which governs how it enters into chemical process.

Hence, magnetism and electricity together provide the enabling conditions for chemistry and chemical relationships. One can thus understand why Kant was at a loss as to how to include chemical process in any rational account of nature . Having restricted reason's grasp of nature to the mechanism of matter in motion, Kant lacked the electromagnetic physical resources to constitute and conceive chemical process.

With philosophical chemistry at hand, it is important to keep in mind a theoretical challenge looming before us. This is the challenge of comprehending how nature can come to contain living beings who can think truly about nature . Chemical process is commonly acknowledged to be a component and enabling condition for the emergence of life, not to mention, of animals and rational animals in particular. Why should this be true? Would there not be life if nature were reduced to the mechanism of undifferentiated matter in motion? Why can there be life only if nature brings electromagnetic process to the point of engendering chemical process? Another way of tackling these issues is to consider whether the developments of physical nature up through chemical process are contingent. Could there be a nature that lacked chemical elements and the relations that ensue between them? Or is it inescapable that nature must have these features? If chemical process provides the enabling conditions for life, including that of rational animals, then nature cannot be known in any respect without actually containing chemical reality and everything else constitutive of intelligent life. To confirm that necessity we must proceed to think through how the chemical development of physical reality leads on to the emergence of rational animals like ourselves. Since, however, the necessity in question is here posed as relative to knowledge of it, there remains the possibility that nature might languish in ignorance of itself so long as it fails to develop beyond the poverty-stricken universe to which mechanist reductionists falsely condemn it.

For Hegel, chemical process is the ultimate "complexity" that nature can attain without becoming a biosphere inhabited by living things. Hegel will conceive life in its emergence in nature in terms of three different stages in development. These will entail a certain temporal succession connected to how the development consists in a succession of enabling conditions for what follows. It will equally, however, be a determination of coexisting aspects of organic nature , whose full constitution will involve them all.

11.4 What Chemical Process Makes Possible: Anticipatory Sketch of Hegel's Threefold Division of Organic Nature

Hegel's threefold division of organic nature begins with the geologic system of the earth, or, more generally of inhabitable planets and moons. [13] He speaks of this geological totality as having a kind of life, anticipating the theory of Gaia, which thinks of earth as a self-sustaining eco-system. In Hegel's specification, this geological system is the potential biosphere that makes life possible, to which he attributes a self-sustaining character, whereby it maintains its own life-friendly environment. Then Hegel introduces the biological reality of plant life, which is followed by the third and ultimate division of organic nature , animal life, on which true knowledge of nature depends. The temporal succession of these developments reflects their order of constitution. Plant life cannot come into being without a geological world to provide the biosphere . Animal life, for its part, cannot exist without plant life, let alone the biosphere they share. Accordingly, if animal life is present, so is plant life and the geological system. With animal life, nature achieves closure, having exhausted the possibilities of natural development. In a fundamental sense, once animal life has arisen and produced rational animals able to know the truth of nature , the universe has nothing new to offer, other than what non-natural history can achieve in its domain.

One might wonder what the geological system adds to nature beyond what the development through chemical process already provides. Although the geological system is composed of nothing more than all the preceding physical processes that follow upon the mechanics of matter in motion, its reality as a potential biosphere involves the supervening self-sustaining process of the "earthly" totality on which life can arise and flourish. This will involve more than the "meteorological process" that provided for the transformation of matter through its different states. Whether the geological system and the forms of life that emerge from it have their sufficient enabling condition in chemical process can only be determined by thinking through what chemistry addresses.

11.5 The Chemistry of Nature

Chemical process exhibits the same principle of electromagnetic polarity at work in magnetism and electricity, but in a different manner. Although chemical process involves factors that contain magnetism and electrical relationships, it has something sui generis of fundamental importance.

Like magnetism and electricity, chemical process is governed by the basic principle of electromagnetic polarity : that like charges repel and unlike charges attract. What is different about chemical nature is how this principle is embodied. Hegel tells us that in the chemical process, the physical factors that enter into it are individual bodies that are themselves totalities, already differentiated through all of the physical processes that have so far developed. [14] These physical materials enter into the chemical process such that the process is going to subject them to alterations in which virtually all aspects of their physical individuation may be subject to change. The chemical process will not simply be a superficial relationship in which charges are exchanged without further affect.

If chemical process may alter the various physical features of materials, then minimally their physical shape will be put in jeopardy. Hegel explicitly acknowledges this, noting that through chemical interaction, the shape of physical bodies will be subject to transformation, together with everything connected to shape . [15] As we have seen, the shape of physical bodies impacts upon how they interact with light, heat , and magnetism , as well as how they smell and taste . Thus, if chemical process alters shape , it alters all these other physical aspects as well.

Chemical interaction will thus involve electromagnetic polarity but in a very concrete way that goes above and beyond what magnetism and electricity effect. Magnetism affords magnetic and magnetized materials moving forces in respect to the principle of like poles repel and opposite poles attract. Until these motions are evident, there is no manifestation of the presence of magnetic polarity . Electricity can be seen and felt through the emission of light and heat that may accompany electrical discharges, as well as when it precipitates chemical transformations. Electricity still remains a predominantly superficial relationship, leaving intact the physical features of the materials through which it courses. In chemical interaction, materials undergo transformations that are predicated upon their own concrete physical individuation. Although Hegel does not invoke differences in atomic structure as bases of chemical affinity, the concrete physical identity of chemicals reflects that structure in ways made tenable by the Periodic Table . This is why the concrete individuality of materials conditions their chemical interaction at the same time that chemical process operates through the electromagnetic polarity underlying how atoms bond into new molecules constituting materials with different physical features.

How then does Hegel characterize chemical process, given that he is oblivious to the atomic and molecular structures with which modern chemistry comprehends chemical reactions? If one has an understanding of atomic and molecular structure, then one can consider how different arrangements and numbers of electrons in electron shells determine bonding possibilities between atoms as well as between the molecules to which they belong. It also allows understanding the results of disrupting existing chemical bonds and what chemical affinities the separated materials will have.

One will also be able to identify chemical elements as consisting of materials with different atomic structures that cannot be further broken apart in chemical, as opposed to nuclear reactions. These chemically irreducible elements will therefore be basic to any subsequent

formation of molecules in chemical reactions. These elements are chemical insofar as they are individuated in terms that dictate how they engage in chemical processes. How they enter into chemical processes is determined by the structure they have, which is defined by the way in which they are composed out of charged components.

11.6 Is Chemistry a Terrestrial Process?

At the beginning of Hegel's account of chemical process, he considers the relation of the earth to chemical process. At times he suggests that the meteorological process is similar to a chemical process, but he also acknowledges that the earth as a whole cannot be engaged in a chemical interaction. [16] To be party to a chemical process the earth would have to be involved with another chemically defined entity on the basis of some catalyst . The relations between the earth and other celestial bodies, however, is not itself a chemical process, although tides and solar radiation have chemical ramifications for particular entities on earth.

More to the point is the question of whether chemical process is something terrestrial, or, more generally, something that can only occur on non-stellar bodies that possess not only chemical materials, but catalysts and sufficient meteorology to facilitate chemical reactions. After all, can there really be any chemistry in the sun or in any other star ? The nuclear fusion fueling stars may generate different chemical elements , but the intense radiation and heat of stellar emissions would seem to prevent the atoms of such elements retaining sufficient stability to bond with one another in persisting molecular arrangements, which could then be disassociated in further chemical reactions. For analogous reasons, stars would be bereft of meteorological transformations of one state of matter into another. Instead of being a domain for chemical process, let alone for meteorology, stars would seem to be restricted to nuclear reactions and the production of plasma . Chemistry, like meteorology, is exclusively a terrestrial reality in the broadest sense.

11.7 Formal Non-chemical Process Versus Real Chemical Process

Before developing the nature and differentiation of chemical process, Hegel distinguishes formal non-chemical process from real chemical process. [17] The formal process involves a combination of chemically distinct materials into a new mixture that in some cases, has properties of its own that differ from those of its ingredients. As examples of formal process, Hegel points to amalgams of materials, mixtures of acids or of alcohol and water, and even alloys. [18] Alloys might appear to involve more than a formal amalgamation, since when metals get combined to form a new alloy metal, its physical properties may radically depart from those of its constituents. How is such a combination not a real chemical transformation?

Hegel maintains that the formal process lacks some of the key features of a real chemical process. First, the materials that will be combined do not have any chemical affinity that causes them to react with one another, even if they were to be ground up and mixed together in a thoroughgoing blend. Second, the formal process does not rely upon any intermediary catalyst . Third, the properties of the ingredient materials do not get entirely lost in the material into which they get "formally" combined. [19] Bronze, for example, may be distinct from the copper and tin from which it is produced, but it retains many of their qualities. For these reasons, Hegel concludes, the formal process does not constitute a genuine chemical transformation at all, but rather consists in a physical process in which different materials get fused together without undergoing the thoroughgoing alteration of a real chemical combination. In the case of bronze, what occurs is that the metals get melted into a liquid mixture that then hardens into a new solid , just as silica may be melted and then solidified into glass. To adopt the language of molecular transformation of which Hegel is oblivious, one could say that the formal process does not alter the molecular structure of the combining materials, but simply achieves a thoroughgoing physical blending.

Real chemical combination, by contrast (1) does unite materials with a polar chemical affinity, (2) does depend upon an external catalyst , and (3) does transform the structure of the materials it unites, which is exhibited in the new molecular organization of the result.

11.8 The Basic Forms of Chemical Process

These defining features of a real chemical process underlie the basic forms chemical reaction can take. Without invoking atomic and molecular structure, Hegel distinguishes two broad types of chemical relation, chemical combination and chemical disassociation . Given that chemical relations will be based upon factors with polar opposition, one can expect that chemical combination will involve the bonding together of chemically opposite materials, just as chemical disassociation will involve their separation.

Chemical combination is not merely physical combination, where solid materials get mixed together, or solids dissolve in a liquid , or liquids mix, or liquids evaporate and mix with a gas . In all such physical combinations the combined materials remain unchanged, other than having passed from one state of matter to another. Similarly, chemical combination is not merely magnetic combination, where magnets and magnetizable materials adhere to one another thanks to the attractive force of opposing magnetic poles. Once more, the magnetic attraction leaves the materials otherwise unchanged. In chemical combination, by contrast, the combining chemicals are transformed into a new chemical product, whose structure unites that of the formerly separated chemicals that produce it. This resultant chemical has throughout a new basic structure, giving it new physical properties of its own, as well as new chemical affinities that determine what further chemical interactions it can enter. Chemical combination thus engenders a thoroughgoing transformation that is anything but superficial. The product of combination does not simply incorporate all the physical properties that its chemical constituents formerly possessed. Rather, its physical properties may deviate entirely from all of theirs, as may its further chemical interactions.

The same can be said of the resulting chemicals that result from chemical disassociation . These may not only be entirely different from one another on every physical register, but they may equally be unlike the chemical whole from which they emerged. Moreover, even if what gets chemically disassociated was itself the result of a prior chemical combination, that does not necessitate that the results of disassociation are the same chemicals that earlier united to form that whole. They may be completely different, depending upon how the two processes proceed.

Like electricity, chemical process will involve a certain polar opposition and an overcoming of that opposition, but in such a way that the total individuality of the materials involved will be transformed. Moreover how the chemical reaction occurs will be based on the physical character of the interacting materials. Nonetheless, in both chemical combination and dissolution, the chemical alteration will not occur unless some external change in circumstances happens that enables chemicals to combine or break down.

This requirement of an external impetus to facilitate the chemical reaction is something that fundamentally distinguishes chemical process from the self-activity of life. Hegel points to this externality as a defining feature of chemical process, which, along with other salient aspects, give chemical process a marked finitude. [20]

11.9 The Finitude of Chemical Process

This finitude of chemical process will provide both one of the features distinguishing chemical interaction and life and an indication of what has to be added to chemical process to engender life. Namely, the finitude of chemical process will have to be overcome in order for organic nature to arise.

Wherein then does the finitude of chemical process reside? Hegel suggests that this finitude resides in a type of determination that is also at play in magnetism and electricity. [21] This determination is that of syllogism. Syllogism is usually thought of as a merely logical relationship. Hegel, however, regards syllogism as a type of determination that can be exhibited both in logic and in different kinds of real processes. Syllogism consists in a process identifying two extremes by means of an intermediary factor. The extremes in question are usually thought of as being an individual and a universal that will be united through a particular, although the development of the different forms of syllogism produces terms that are more and more intrinsically connected. [22] Nevertheless, the key to the syllogistic process is that the two extremes are going to be connected to one another by means of a third factor. How is such a process connected to the finitude of chemical relationships? How does syllogism get concretely exhibited in chemical process?

The syllogistic process seems more evident in the first form of chemical process, that of chemical combination. In chemical combination, two distinct chemical factors are going to be united. Where, however, does the syllogistic element come into play? Where is the intermediary that serves to unite these distinguished factors? The answer is to be seen in how chemical combination occurs. It does not take place immediately, that is, without some intervening mediation. Chemical reaction does not just occur given the presence of chemically opposing factors. There must be some catalyst , some third factor, which allows their chemical tension to resolve itself in combination. The same dependence upon a catalyst applies to the chemical reaction where some chemical becomes disassociated into two new independent terms. In this respect, disassociation embodies syllogism as well, since the resulting “extremes” are related to their antecedent unity through the catalyst that precipitates their emergence. Otherwise any chemical subject to disassociation would instantaneously vanish into other chemicals, which would instantaneously combine, unless they were chemically inert.

The dependence of chemical reactions upon a third factor is connected with another aspect of chemical process that expresses its finitude. Namely, a chemical process does not renew itself on its own. It does not kindle itself, it has no self-maintaining, self-positing character. The chemical relationship cannot get underway in and of itself. Rather, its occurrence is conditioned by something external to the chemicals that get combined or disassociated. Not only must there be a catalyst , but the chemicals must be placed in sufficient proximity, as well as be under sufficient pressure and temperature conditions. These precipitating requirements are not supplied by the chemicals themselves that undergo chemical transformation. So conditioned, chemical process is finite.

Another side of chemical process that exhibits its finitude is the difference between its starting point and result. Whether chemical reaction results in a combination of two chemicals into a new material with a distinct molecular structure of its own or in the disassociation of a chemical into two or more different chemicals, there is a discrepancy between the beginning and end of the chemical process. This discrepancy reflects how chemical process is not self-

renewing, since in order to kindle itself, the chemical relationship would have to return to its starting point for another initiation of its reaction. Instead of ending in the chemical/s and catalyst from which it began, chemical process results in a different chemical or chemicals, for which any abiding presence of the original catalyst will precipitate a different outcome than before, if it precipitates any chemical reaction at all. To be self-renewing, chemical process would have to generate the same chemicals, catalyst and external conditions that kindled its original engagement. This would signify that the process would generate its own conditions and cease to be externally activated. As Hegel will emphasize in his account of organic nature , the life process deviates from the chemical reactions it contains by being self-sustaining and self-activating, even though it must relate to its biosphere to do so.

Although the two basic chemical processes, combination and disassociation , are not self-renewing, do they together provide a self-sustaining chemical activity? It is important to keep in mind that combination and disassociation are different processes. Even if what gets dissociated is a chemical that results from the combination of other chemicals, dissociation need not produce the same chemicals from whose combination the dissociated chemical may have resulted. Although the incorporated atomic structures may be the same, the molecular structures may be broken apart in different ways, just as an array of the same types of atoms may be combined into different molecular arrangements. Nonetheless, if one takes the totality of chemical processes, could it altogether involve the same chemical factors as both starting-points and products? Admittedly, the same factors can figure as both starting-points and products, but not of the same chemical process. Rather, the same chemicals could be the starting point of a certain chemical combination and also be the result of a different chemical disassociation. Alternately, the same chemical could be the result of a certain chemical combination and be the starting point of a different chemical disassociation. In every case, however, the chemical reactions will still depend upon externally given catalysts and facilitating physical conditions, even though the requisite chemicals may be generally at hand. In particular, the relevant chemicals must not just be continually made available, but be in sufficient proximity to themselves and the catalysts they need under the requisite local conditions.

Even if the combination of the two forms of chemical reaction may not constitute a self-renewing total chemical process in and of itself, it does provide the resources that can in the right local circumstances initiate the self-renewing process constitutive of life in its most rudimentary form.

To be self-renewing, a process involving chemical reactions must consist in components that are both prerequisites and products of the process, including any catalysts and physical conditions on which the reactions to be renewed depend. No single chemical reaction can meet these requirements, nor can chemical reactions in their totality reproduce themselves. Nonetheless, the possibility remains that, out of sheer physical happenstance, the right chemical reactions could occur in the appropriate facilitating environment so as to produce together their own initial conditions and achieve the self-kindling of a self-renewing process.

Such a scenario is envisaged by modern biologists who conceive life to involve minimally an “autopoiesis”, a self-making process, which continually produces the conditions for its own perpetuation. [23] They describe such autopoeisis as involving chemical processes operating within a determinate physical boundary so as to fulfill two provisos on which self-renewal depends. First, the chemical processes that occur within this enclosure fit together in such a way that the products of the various contained processes provide all the inputs that each requires. Secondly, these chemical processes must also reconstitute and preserve the boundary within which they

occur, such that their enclosure allows entry to whatever is needed to continue the interior activity and to expel whatever byproducts cannot be recycled. In this way, the coordinated chemical processes establish something akin to a basic cell structure. The boundary of such a cell comprises a permeable membrane that lets in what the total process needs to continue, as well as gets rid of what the total process does not need and must expel so as not to interfere with the continuance of the requisite chemical reactions by which the cell maintains itself. Thereby chemical process becomes enlisted in the constitution of a new type of natural being, the self-preserving activity of an organism .

11.10 The Catalyst in Chemical Process

The two basic chemical processes both involve the mediation of extremes by a third term, albeit in reverse order. Both processes involve a chemical affinity of two materials, which are united in a new molecular structure in combination and brought into being by disassociation. Although the products of disassociation may not be primed to recombine into the material from which they arose, within that material they have an implicit chemical attraction that must be broken apart by the introduction of some catalyst . Chemicals that have an affinity to combine are such that they have, as Hegel puts it, an urge to unite with one another. [24] They have a distinctly chemical polarity , which is different from the attraction of unlike and repulsion of like poles of magnets or the voltage tension of materials whose aggregate charge is ready to be neutralized in electrical discharge. What makes the polarity chemical is that it does not just bring the two materials to stick together or transfer charges while retaining all other physical features. Instead, the opposition of chemical affinity involves an urge to become transformed into a new unity, whose physical properties have no inherent connection to those of the chemicals it bonds together. Alternately, chemical disassociation will not involve the mere separation of formerly attracting entities or the rupture of an electric current. Rather, chemical breakdown will give rise to the production of chemicals whose properties have no connection to those of the disassociated chemical or whatever chemicals may have previously combined into its formation. In both types of chemical reaction, chemicals undergo fundamental qualitative changes.

What then is the precise role of the catalyst in each form of chemical process? In the case of chemical combination, the catalyst will do something without which the chemically opposed materials cannot bond together. Does this signify that the catalyst combines with them into the resulting product? If so, the catalyst would merely be another chemical with an affinity for its two partners and chemical combination would proceed immediately, without any intermediary. In that case, any chemical tension would instantaneously collapse and chemical process would vanish just as quickly as would any chemical affinity. Instead, the catalyst must do something that is not itself a chemical process of combination or disassociation , yet is necessary to activate the ensuing chemical reaction.

The chemical agents do not in and of themselves bring themselves into chemical relationship. Something independent of them must bring them together so that their chemical affinities can react. One might imagine that this is simply a matter of movement, which brings the chemical materials close enough to begin their chemical reaction. In this vein, Aristotle had suggested that locomotion was the basis for all other changes because substances have to make contact in order to undergo further alterations. [25] Chemical reaction, however, requires more than just bringing materials into proximity or even bringing them into contact. Chemical process is not a superficial relationship, but a thoroughgoing transformation of the chemicals that participate. For just this reason, the chemicals cannot have their affinities activated unless the “contact” is a thoroughgoing one, where all parts of each chemical material can enter into the bond by which they are transformed into a new chemical material. Thus, to activate the chemical reaction, more must be done than simply allow a current to pass through material, altering its aggregate charge. To precipitate a chemical reaction, an electric current must pass through all parts of the chemically primed materials, as in galvanization, so that it can precipitate a new bonding of atomic or molecular components.

Generally, whatever serves as the sufficient catalyst for chemical reaction must facilitate such

thoroughgoing contact that allows the chemical affinities of all basic components of each material to come into play. This requires overcoming the resistance to thoroughgoing connection presented by the external shape of each material. A catalyst can achieve this by physically breaking down the resisting shape by, for example, dissolving the materials into a solution in which their elementary components can all come sufficiently close to have their chemical affinities take over and bond them together. The same breakdown of resisting shape can be achieved by using sufficiently strong sound waves or sufficient heating to enable the parts of each material to make intimate contact.

In identifying catalysts, Hegel refers to what he describes as the two elements of opposition, air and water. [26] Properly speaking, these "elements of opposition" are more generally the states of matter , liquid and gas , and they provide a privileged physical source for catalysts. What makes liquids and gases likely candidates for catalysts is that they both can break down the physical shape of chemicals and allow them to intermix sufficiently to react chemically. Liquids achieve this by dissolving solids and diluting liquids, whereas gases achieve something similar by evaporating liquids and, to a lesser degree, solids, allowing the vaporized materials to blend together in a gas mixture susceptible of kindling a chemical reaction.

Through this physical reduction of shape , the catalyst precipitates the chemical reaction without having itself to undergo any chemical transformation. Although the catalyst need not chemically alter, it is still a constitutive factor in chemical process, the necessary third term that mediates the materials primed to chemically react. The catalyst , in the most minimal sense, can be completely chemically neutral with respect to the ensuing combination.

On the other hand, while facilitating a chemical reaction, the catalyst could end up being drawn into a chemical process as well. For example, in the first chemical process of which Hegel speaks, the galvanic process, metals that are otherwise chemically inert with respect to one another will chemically react when they are put in a proper solution through which an electric current is run. The solution is not just water, but water containing salts. The water gets broken up into hydrogen and oxygen and one metal becomes oxidized, whereas the other attracts hydrogen, with which it may combine or undergo deoxidation. [27]

Another example is the process of combustion. Here again a physical process of heating must be brought into play to precipitate a chemical reaction, in this case oxidation . The introduction of heat allows a chemical combination to occur that would not occur without it. Somehow increasing the kinetic energy of the components of the combustible material facilitates its oxygenation by breaking down its shape , so as to make its contact more thoroughgoing, as well as to facilitate the transfer of electrons between electron shells by which the chemical combination is achieved.

Although a distinct chemical may not here serve as a catalyst , the chemical process still remains contingent upon a third factor, which may just as well be an introduction of heat or electric current, as well as a liquid in which reacting materials can dissolve.

If such a third term were not needed, the chemicals would immediately attract their counterparts and merge with them and disappear, just as any chemical subject to disassociation would immediately break apart. Chemical process would thereby cancel itself, leaving behind nothing but chemically inert materials. Instead, chemical reactions are contingent upon something more than the reagents themselves.

Nonetheless, there is a chemically defined "inertia " that certain materials may possess, preventing them from being susceptible to chemical transformation. Materials are chemically inert because their structure is such as to prevent other chemicals from combining with them into

new chemical substances as well as to prevent other chemicals and catalysts from breaking them apart into new chemicals. Chemical inertness is thus distinctly different from mechanical inertia . The inertia of undifferentiated matter pertains to how motion is something external to it. A body exhibits inertia by only undergoing a change in motion owing to the application of some external moving force. By contrast, a material is chemically inert insofar as its chemical structure prevents it from undergoing any chemical transformation. Such a transformation has nothing to do with locomotion , but rather concerns chemical composition, which differentiates materials with respect to the electromagnetic structure of those elementary components that enter into chemical bonding.

There is, however, something common to inertial mechanics and chemical process. Both involve changes that depend upon external conditions. Inertial bodies do not alter their movement by themselves any more than chemical processes kindle themselves. Even though chemicals are primed to enter into certain kinds of transformations due to their specific chemical identities, their chemical activity is not a self-activity, but depends upon a catalyst and associated precipitating conditions. Chemistry may no longer concern the formless matter of inertial mechanics, but it still involves physically differentiated materials that are unable to chemically transform themselves on their own.

Although chemical dissociation may less evidently embody a syllogistic relation whose extremes are mediated by a third term, it still requires something external to set off the ensuing decomposition. Hegel points to salts, which result from the combination of an acid and a base , as being the paradigmatic subject for chemical dissociation. [28] Some catalyst must interact with the salt to cause it to break apart. Since disassociation comes to an end with the production of at least two chemicals that are not then going to immediately recombine, these products must be chemically inert with respect to one another in the conditions under which they emerge. This suggests that the salt will not disassociate into the acid and base from which it arose in the first place . Thus, connecting the chemical combination producing the salt with the salt ’s chemical association does not produce a circuit whose starting point is identical to its conclusion. More generally, since chemical combination and chemical dissociation both depend upon external kindling, chemical processes will not lead to further chemical reactions unless sufficient facilitating conditions come into play.

Broadly speaking, any processes that are externally determined are subject to utilization by processes that are of an entirely different character. Insofar as mechanical and physical processes all involve external conditions, they can be enlisted by the qualitatively distinct processes of life and technique . An organism can incorporate chemical reactions so as to sustain itself and thereby subordinate them to its self-perpetuation as an end in itself. Similarly, an agent can use chemical reactions to produce an artifact , subordinating them to the realization of the design that the artifact embodies. The external impetus of inorganic processes is why teleology can enter into nature , even if mechanics and physics are in and of themselves causally “blind”, that is, devoid of any guiding telos. Mechanical and physical processes can all be put at the service of the realization of ends belonging to life and rational intelligence precisely because they are subject to external determination.

What allows chemical process to not only serve life, but give rise to the self-renewing activity of an organism in the first place , is that the starting points of both chemical combination and chemical disassociation can all be the products of other chemical reactions. Hence, chemical process provides for the possibility of chemical reactions by chance becoming integrated into a self-renewing system of chemical transformations providing for the minimal autopoeisis of the

most elementary form of life. This can only occur by chance since no chemical, let alone physical or mechanical process can produce such a system by itself. Although gravitational systems may constitute a self-moving solar system , some of whose bodies may have meteorological processes, they lack the self-kindling chemical transformations that will prove to be ingredient in life.

Another factor to consider in examining how chemical process provides the enabling conditions of life is the relationship of the organism to inorganic nature . Although animals and certain plant-like organisms like mushrooms live off other organisms, plant life characteristically survives off inorganic material. Plants typically achieve photosynthesis thanks to light, water, nitrogen, and the chemical reactions by which these factors provide plants with the energy and molecular materials they need to sustain themselves.

Our own being, as well as that of all other life forms, thus depends upon the physical development of chemical elements , without which chemical process cannot occur. Reason cannot itself dictate what these elements are and what specific chemical relationships they can foster. Philosophy can, however, think through how electromagnetic polarity allows for magnetism , electricity, and the formation of chemical reagents that can combine or become disassociated through the external facilitation of catalysts and appropriate physical conditions. The atomic theory of nuclei and electron shells provides a framework by which these basic provisos of an a priori chemistry can be further concretized, in conjunction with a nuclear physics that makes intelligible the ignition of stars and the solar emission of light and heat with which planetary bodies can become biospheres. All this is conceivable without having to construct an a priori Periodic Table . By the same token, the philosophy of nature will move from chemical process to life by conceiving a universal biology that cannot and need not be confined to any particular elements (such as a carbon based organic chemistry) , nor to any specific super molecules (such as RNA and DNA).

Hegel, however, seeks to develop chemical process beyond the basic divide of chemical combination and chemical disassociation . Hegel does this by identifying specific types of chemical elements that are differentiated by the kind of chemical reactions in which they are able to participate. In this way, Hegel distinguishes acids from alkali (or bases) and introduces salts and metals as specific chemical groups. [29] Obviously, chemistry, as an empirical science, does acknowledge these types of chemical materials, as well as the types of chemical reactions to which they are subject. Are these kinds of divisions necessarily built into chemical process? Do these represent genuine generic types of chemical elements?

11.11 Hegel's Differentiation of Chemical Elements

Hegel offers several ways of differentiating the chemical elements . In paragraph 328 of the *Philosophy of Nature* , as well as in the addition to the same paragraph, Hegel distinguishes four chemical elements that supposedly reflect the generic features of chemical process. [30] He identifies these as nitrogen, oxygen, hydrogen, and carbon. Nitrogen exemplifies chemical indifference. Like other inert noble gases, nitrogen will not usually chemically interact with other materials. By contrast, Hegel distinguishes oxygen and hydrogen as the elements of chemical opposition. Oxygen is the consuming element and hydrogen is the combustible element, comprising the two sides of the process of oxidation or combustion. Carbon, for its part, is described as the paradigmatically individual element, which can stand on its own. Hegel maintains that the other three chemical elements lack this independence by existing separately only thanks to external force, leaving them with a momentary existence. [31] Although oxygen and hydrogen may well be primed to combine easily with other chemicals, including one another, this is hardly the case with Nitrogen, or, more generally, inert chemical elements, such as the Noble gases. Hence, if carbon is to represent a fourth type of chemical element, its connection with certain types of chemical reactions must be further established. In general, it is far from clear how these four elements are representative of the components of all chemical processes, nor does Hegel make any argument to show that all chemical substances are composed of these four elements in different combinations.

What Hegel does do, however, is proceed to develop the putatively fundamental forms of chemical combination, which he presents in a series of processes in which different types of chemicals participate. Hegel here offers four basic types of chemical combination, which he identifies with galvanism, combustion, the neutralization of acids and alkalis, and finally, the process of elective affinity, where acids and alkalis dissociate themselves from neutral salts and recombine with other acids and alkalis with which they have a greater "affinity". These chemical processes each embody a different type of syllogistic relationship, that is, a different manner of uniting extremes, and Hegel presumes that they exhaust the basic possibilities of chemical combination.

Starting with galvanism, Hegel ties metals to this allegedly most elementary chemical process. [32] Metals are here identified as the kind of chemical elements that are, to begin with, chemically indifferent and inactive in and of themselves. Their inert character is overcome by bringing them into a chemical tension through something else. They have to be immersed in some liquid medium, like water, such that when an electric current passes through them, their chemical difference can actualize itself in a transformative reaction. Hegel acknowledges that the simple galvanic cell, in which two different metals are submerged in water through which electricity passes, does not produce a new type of chemical material, but only an eventual combination of the metals, where one coats the other. [33]

When, however, a single metal is immersed in a liquid like water, through which an electric current courses, this most basic galvanic reaction produces a second kind of chemical entity: the metal oxide that forms when the water gets disassociated into its components, hydrogen and oxygen, and the released oxygen combines with the metal. This process implicitly consists of oxidation , which more generally involves the reaction whereby some chemical material gets combined with oxygen into a new chemical substance. In the case of galvanism, oxidation is produced by means of an electric current, which presumably affects the molecular structure of

water as well as the distribution of charged particles, facilitating the ensuing oxidation .

Although Hegel associates oxidation with combustion, he presents combustion as a distinct process, where the chemical combination occurs by means of fire in which what is combustible is itself consumed by flame. [34] This "consumption" by fire is not merely a change of the combustible material's state of matter from solid or liquid to vapor, but rather a chemical transformation, where the material combines with oxygen. The combustible material, whose oxidation is kindled by fire, is not a metal, but a different type of chemical element, whose combination requires the facilitation of the heat generated by the fire. A metal may be melted by the flame, but, ordinarily, it will not ignite.

One might wonder to what extent this type of chemical reaction can be freed from a connection to the specific element of oxygen as well as to any specific combustible element. When Hegel ties metals to galvanic reactions, he is not identifying a single element, such as oxygen, but rather a class of chemicals, the metals, whose commonality is exhibited in how they enter into the particular chemical combination process of galvanism. The same generality applies to the third type of chemical combination Hegel identifies, which involves the neutralization of acids and bases. This type of reaction is not ascribed to the relation of a specific acid and alkali, but rather to any chemicals that are acidic or alkaline. Finally, the fourth type of chemical combination process Hegel introduces, that involving "elective affinity", also pertains not to a specific acid and base that have a special affinity to one another, but rather to any acids and bases that can have that relationship.

One way of reconsidering combustion in more apt general terms is to consider what happens in oxidation to the combustible material. Oxidation involves a particular kind of transfer of electrons, which conceivably can occur with other chemical elements . When one thinks of chemical relations in terms of the electromagnetic polarities involved, including the atomic structure of different elements, then one can perhaps distinguish different types of chemical reactions in terms of how bonds are formed or broken in respect to the specific electron shell composition of the reacting elements.

Hegel, of course, does not appeal to atomic structure, but instead focuses on the types of relationships between the chemical extremes and their mediating factor. These relationships are tied to types of chemical substances. Galvanic reactions involve metals, but give rise to oxides. Combustion involves chemicals that are combustible, that is, made susceptible to combination through subjection to flame and its heat . Given Hegel's connection of combustion to the specific process of oxidation , the chemicals participating in combustion are those that can be oxidized by means of fire. Without that exposure, combustibles are relatively inert, and only the catalyst of fire brings them into a chemical tension to the combusting factor (in Hegel's case, oxygen), that the ensuing combination resolves.

The third type of chemical reaction, on Hegel's account, is the neutralization process where acids and bases are mixed into a liquid in which they combine to form salts. [35] Acids and bases are extremely reactive opposites and the chemical character of salts reflects how their neutralizing combination produces a chemical that overcomes the acid -base opposition. The identity of a salt thus depends upon the identity of acids and bases and the chemical specificity of their active opposition. Hegel himself has little to say about what generally distinguishes acids from bases. Instead, he points to different chemicals and identifies them as acids or bases. Both acids and alkali are corrosive and destructive of chemical materials that otherwise are stable. Hegel does characterize acids and bases as polar chemical opposites, but has little to offer as to what makes a material an acid or base . Modern chemistry distinguishes acids and bases in terms

of how they relate to the electrons of other elements, where acids take up pairs of electrons from other substances, whereas bases operate conversely, donating electrons to other materials or acquiring a hydrogen ion, which, having lost its solitary electron , has a single proton positive charge.

The result of acid /base neutralization comprises a salt , which generically constitutes the chemical in which, through the medium of some liquid , an acid and an alkali combine, eliminating their unstable opposition. Because salts join together acids and bases, salts can operate as the extremes of a distinctive chemical reaction in which their polar components get exchanged. This exchange comprises what Hegel identifies as the fourth fundamental form of chemical combination, developing it under the heading of "elective affinity". [36]

In the process of elective affinity, neutral bodies, each resulting from the combination of an acid and a base , are incited to react with one another. Since both of these extremes are neutral, they must be brought into opposition by some catalyst . This can be achieved by the dissolution of the salts in some liquid that brings their components into sufficient proximity for their molecular components to come under the sway of their electromagnetic arrangements. This then allows the salts to undergo an exchange of their acidic and alkali polar elements, where the acidic element of one salt comes together with the opposing alkali of the other salt , and the alkali of the first salt gets combined with the acid within the other salt . This dual exchange confirms that the acids and bases that come together have an "elective" affinity, superseding the polar opposition that first produced the salts that now have reacted to produce two new salts of a different composition.

Have the four types that Hegel has delineated, galvanism, combustion, the neutralization of acids and bases, and elective affinity, exhausted the possibilities of chemical combination? Insofar as Hegel links specific types of chemicals to each type of chemical process, the extremes are differently determined in each case. In galvanism, the extremes are both metals that have no given chemical affinity for one another and must be subject to an electric current while immersed in a liquid in order to react. In combustion, the combusting factor (oxygen) and the combustible material are of differing chemical types susceptible to combining when subject to fire. In the neutralization process of acids and bases, the extremes are highly reactive chemical opposites, whose facilitated contact produces a chemically neutral salt that eliminates the reactivity of the chemicals it unites. Finally, in the interaction of elective affinity, the extremes are two salts which, when subjected to the right conditions, exchange their component acids and bases, resulting in a new pair of different salts.

One cannot match these processes with the forms of syllogism that Hegel develops in his *Science of Logic* for the simple reason that Hegel offers only three basic forms, the syllogism of determinate being (or qualitative syllogism), the syllogism of reflection (or quantitative syllogism), and the syllogism of necessity (which concludes with the disjunctive syllogism). Although there may be four forms of judgment (qualitative judgment, quantitative judgment or judgment of reflection , judgment of necessity, and judgment of the concept), these three forms of syllogism exhaust the logical possibilities. There can be no syllogism of the concept because the preceding disjunctive syllogism removes the difference between the extremes and their mediating term, on which the form of syllogism depends. [37] In any event, the logical development of syllogism cannot of itself guarantee any closure to chemical process, unless one can show how the forms of chemical process can be distinguished by the logical form of the syllogistic relationship they allegedly embody. Hegel does not provide a sufficient account of any such logically based possibilities and the chemical relationships must speak for themselves.

They must show that there can be no other types of chemicals than these allegedly exhaustive chemical combinations involve, as well as that these chemical reactions somehow cover all possibilities of chemical combination.

Given that chemical reactions involve combinations or disassociations of materials that get transformed into products of a different chemical character, thanks to some external catalyst , one may consider the general possibilities. If chemicals were simply individual and devoid of any groupings, then there would be little more than two types of chemical reactions: (1) the externally facilitated combination of two different chemicals into a third chemical of a different identity, and (2) the externally precipitated disassociation of a chemical into at least two other chemicals different from it. If, however, chemicals fall into types that define the chemical reactions in which they enter, further distinctions are possible. First, combination could unite two chemicals of the same type to produce a chemical of the same type. Second, combination could unit two chemicals of the same type to produce a chemical of a different type. Third, dissociation could result in two or more chemicals of the same type that are of the same type as the chemical that is broken down in the reaction. Fourth, dissociation would result in two or more chemicals of the same type that all differ in type from the chemical from which they separate. On the other hand, if there are types of chemicals that are not just different, but polar chemical opposites, like acids and bases, then the following further options result: First, combination could unite two chemical opposites in a neutralizing product. Second, combination of two chemicals that are not polar opposites could result in a chemical that is a polar opposite (e.g. an acid or base). Alternately, disassociation could break down a chemical into two or more different chemicals of the same or different type as that from which they originate. In the case where the disassociated chemical produces chemicals different in type from itself, these could be of the same or different type themselves. In the latter case, disassociation could break down a neutral product (e.g. a salt) into polar chemicals (e.g. acids and bases), or possibly into polar chemicals together with chemicals that are not polar opposites. Finally, chemical process could combine combination and disassociation in the manner of elective affinity, whereby two neutral chemicals, each containing components that can have a separate life as polar opposites, could exchange these opposing elements, producing two different neutral chemicals.

This taxonomy of chemical relations would not itself specify all the types of chemicals that are not polar opposites, but it would provide a general division of polar opposing chemicals, the chemicals that are products of the neutralization of such polar opposites, and other chemicals that have no polar opposition, including substances that are chemically inert. In addition, the taxonomy of chemical relations could provide a grouping of catalysts according to which type of chemical reaction they facilitate.

Whether or not Hegel has succeeded in exhaustively determining the types of chemical reactions, he has highlighted how chemical combination and chemical dissociation not only transform given chemicals, but do so in types of reactions that involve types of chemical substances. Whether these types are susceptible to an a priori taxonomy, they have a common consequence: the identity of chemicals is revealed in the cycle of chemical reactions in which they participate. Whether entering as a given starting point or emerging as a product, each chemical exhibits its identity in processes that transform all the physical properties of the reagents.

11.12 From Chemical Process to Life

Philosophical chemistry achieves closure when it is in a position to determine the dividing line between chemical process and life as well as how chemical reactions make possible organic nature . What distinguishes the process of life from mere chemical process? How and why does the emergence and sustenance of living things depend upon chemical reactions, and not just the mechanical and physical aspects of nature ?

The relation between life and chemical process is hard to ignore, for life has an acknowledged chemistry of its own, the whole domain of so-called organic chemistry . Life, however, is not reducible to the reactions of organic chemistry and the chemicals specific to it. In and of themselves, the reactions of organic chemistry and the chemicals these contain involve the same type of finite, conditioned transformations that characterize chemical process. Although living things may incorporate organic chemistry , the life process is something more than the chemical reactions and chemical elements it contains. If it were not, life would be reducible to chemistry and forfeit all the defining features of organic nature that we are on the verge of conceiving.

Hegel indicates how life is intrinsically connected to, yet irreducible to chemical process, by suggesting that life is a chemical process made perpetual. [38] *If* the products of chemical process spontaneously renewed their activity, they would constitute life. [39] In suggesting how life consists in chemical processes that have become self-renewing, Hegel is giving us the divide between the inorganic and the organic. Chemical process, by itself, does not perpetuate itself. It is finite, depending upon externally given catalysts and facilitating conditions that each chemical process fails to provide for itself. This is exhibited in how every chemical combination and chemical association begins and ends with a different array of chemicals. Not only is every chemical reaction conditioned, rather than self-activating, but it leads to a result that is different from its starting point. Life, by contrast, is self-renewing. Although life may depend upon external conditions that allow for the organism to exist, the organism sustains itself, undergoing constant internal transformation that renews its constituents and the transformative process itself. Whereas chemical process extinguishes itself in arriving at a result different from its point of departure, the life process functions as an end in itself, producing nothing other than the process in which it consists.

Why does the self-renewing process of life depend upon chemical process and incorporate it in something that does what no individual chemical process can do: namely function as a self-kindling, self-sustaining process? Life in some fundamental respect is continually asserting itself at the same time that it liberates itself from the given material in which it exists at any point in its life cycle. The life process cannot be reduced to the imposition of form upon a given material, in the manner of artifact manufacture. The artifact does not continually renew itself, let alone undergo any transformation that could be identified with an active self-production. Nor can the life process be reduced to any mechanism of undifferentiated matter in motion. The self-renewing activity of life is intrinsically connected to its specific constitution, since it consists in nothing but the self-production of what it is. Its “motion” does not concern change that leaves its matter unaltered. Nor does the life process simply consist in the physical processes where materials possess a shape that determines their interaction with light, sound , heat , magnetism , and electricity. None of these processes involve the thoroughgoing transformations that life is continually imposing upon itself and its own material. Unlike the self-active life process, the

growth of a crystal only adds inactive shaped matter to material of the same fixed configuration. The living thing, by contrast, is always transforming its own material so as to perpetuate its living functions, whose cessation is death , reducing the organism to material subject to external determination.

In order to be self-producing in any thoroughgoing way, life must enlist chemical process, for only chemical process involves transformations that are not superficial. The chemical process, Hegel observes, is in *general* terms life, insofar as chemical process not only produces chemicals, but destroys them in its reactions. [40] Admittedly, the beginning and end of chemical process are separate and distinct. Nonetheless, chemical process produces the thoroughgoing physical transformation without which self-renewing self-production cannot occur. To be a self-producing entity, whose continuing process renews itself, the organism must be able to combine its components into new material, as well as disassociate material into the components from which combination can begin anew. Although no single chemical combination or disassociation achieves both requisite transformations, the proper fortuitous integration of a plurality of chemical processes can engender a total process whose inputs and outputs are identical, together with the catalysts necessary to renew the respective reactions.

In this way, the properly integrated chemical process can become perpetual, kindling the life process in its self-kindling repetition, which, admittedly depends upon interaction with a biosphere in order to obtain new energy . This confirms Hegel's point, that if the products of chemical process spontaneously renew their activity, they would be life. Here, chemical reactions give rise to life by equally becoming subsumed within the organism 's self-activity.

The divide between inorganic and organic nature is therefore not an external boundary. Rather, organic nature incorporates all that is ingredient in chemical process, while giving chemical reactions a new type of integration constituting an entity of a distinctly biological character.

In distinguishing chemical substances from living organisms, Hegel points out that the species of the chemical body is a fixed entity identical in character to its substantial nature . By contrast in the organic realm, the species is not identical with the substantial nature of the individual. [41] The individual living thing has an individuality that is not completely determined by its species being. As the reproductive process will make manifest, organisms do not have their species being in their individual existence, but only through the generation of other organisms of the same type, who differ as individuals. The species of organisms will exist only in the emergence and death of distinct individuals. Chemicals, on the other hand, will be completely identical to others of the same species . Although acids may include different types of acids, each of these chemically identifiable acids will be indistinguishable from one another, apart from the nuclear differences of isotopes . Moreover, chemicals will not themselves undergo transformations apart from their combination or disassociation in chemical reactions. They will remain rigidly unaltered in and of themselves, whereas organisms will be in continual process, apart from periods where they put themselves in suspended animation, as in the cases of spores and hibernating animals.

Despite these fundamental differences, life both arises from and necessarily contains chemical process. Chemical process may not itself be alive, but it provides the enabling conditions for life to arise. Life will not be the product of any particular chemical reaction, nor will chemical processes necessarily integrate themselves into the self-sustaining process of the organism . Rather, the emergence of life will occur through the contingent concatenation of the requisite chemical reactions such that the basic autopoeisis of life can get underway.

This transition from inorganic to organic nature , so immensely important, therefore need not occur in every corner of the universe. It *may* occur on any of those planets and moons where the requisite physical and chemical processes are present. Indeed, there is no guarantee that it will take place at any point in time or after any interval in the natural history of galaxies and their solar systems. Nonetheless, we, who think the true character of nature , cannot coherently deny that this transition has taken place on our lonely planet .

The emergence of life from chemical process sheds light on the general character of transitions in the philosophy of nature and of developments in the self-constitution of nature . At every step along the way, more elementary natural processes give rise to more concrete processes that have their greater complexity in virtue of incorporating the processes from which they arise. For this reason, the more concrete processes can neither be conceived nor be actual without the conception and being of their more elementary antecedents. In no case does the more elementary natural process determine what builds upon it. Rather, the more concrete natural reality is determined in and through its own distinctive operations, which nonetheless need nothing more than the more elementary natural factors as its constituents. In other words, the more elementary natural factors are not determining principles of what forms upon their basis. Rather, they remain enabling conditions for something that is governed by principles of its own. This is why there is no chemical necessity that chemical reactions come to be integrated into a living organism . There is, however, a chemical possibility, rooted in the actuality of chemical process, which allows life to arise by chance .

Hegel discusses how the nature of chemical process contains what will undermine its own defining finitude and external determination and set the stage for an internally determined self-active life process. In paragraph 336 of the *Philosophy of Nature* , he points out that chemical process itself negates its own immediate presuppositions on which its finitude and external determination rests. [42] Chemical process does so by both transforming and eliminating the very chemicals from which its combination and disassociation reactions proceed and then equally producing them as results of these processes. Every chemical factor that functions as the immediate presupposition of chemical reactions is negated by those reactions and equally produced as the outcome of some other chemical process. Everything that enters into chemical reactions equally turns up as their product. In this way, chemical process as a whole provides for its own presuppositions, implicitly overcoming the finitude and external conditioning of each of its reactions. The living organism provides the positive result of this implicit overcoming by explicitly consisting in a self-renewing system of chemical processes, which now can develop its own biologically specific nature . Life confirms how once a process generates its own conditions, it becomes unconditioned or self-conditioned. Such a process loses the finitude of being conditioned by something else, something outside of it. It loses this external dependency and instead activates itself. Chemical process makes this possible, for, as Hegel notes, it renders relative the properties and being of its immediate substances. [43] Their entire given character is continually superseded in chemical reactions which, as a whole, not only transform their inputs, but produce them as outcomes of its own process. Whereas chemical process begins with chemicals and catalysts whose presence is the condition of its operation, these factors end up being mediated by chemical processes that produce them in turn. If everything that serves as a condition of a process equally turns out to be mediated, to be a product, of that process, then the process as a whole ends up accounting for its own presuppositions by generating its own conditions.

Admittedly chemical process achieves this through separate chemical reactions, none of

which account for their own conditions. Nor do chemical reactions assemble themselves with any necessity into a particular entity whose constitutive chemical processes are self-renewing. Once life emerges, however, the chance occurrence of such an assemblage is itself overcome. Now the self-renewing organism strives to maintain its new life process, both in its own individual reality and in the species being that reproduction establishes. These are no longer chance occurrences, but constitutive aims inherent in life. Organic nature will not let itself give way to external circumstances, but instead will struggle to survive and reproduce in face of all the external influences of mechanism , physical process, and chemical reactions.

Life will necessarily involve a multiplicity of chemical relations. What is specific to the organism is that in all chemical relationships it contains, it returns to itself, producing itself in and through these chemical reactions. The living thing is self-preserving even though, as Hegel says, it acts and reacts against the most diverse external powers. [44] It is differently determined in each of the reactions it engages in, but it nevertheless maintains its unity. It manages to sustain itself and it is not neutralized in the way in which a chemical gets neutralized in a chemical relation, resulting in a product different from itself. In neutralization, as well as in any other chemical reaction, the chemicals lose their identity, here getting transformed into a salt , from which there is no guarantee that out of that salt will come the same acids and bases which went into it. The organism , however, despite all the multiplicity of chemical relationships within which it engages, ends up sustaining or producing itself. This return to self is what distinguishes the metabolism of the living organism , which of course involves chemical interactions. Although each of its constitutive chemical reactions ends up with chemicals different from those with which it begins, the entire metabolic process transforms what is different from the organism into the active living material of its own self.

For this reason, Hegel can characterize the organism as having a self-subsistent infinite form. [45] It is easy to grasp how life has a self-subsistent form insofar as the organism spontaneously maintains itself. How can, however, the organism be in any sense infinite? The finite is characterized by having a limit, a beyond. Such limitation applies to anything determined by something else, anything conditioned. Obviously an organism has conditions that enable its life process to proceed. These conditions reflect how the organism has a beyond consisting in the biosphere in which it survives. Nonetheless, these external conditions facilitate nothing other than the self-sustaining activity of the organism , which has itself as its own product. Instead of subjecting the organism to alterations determined from without, the biosphere makes it possible for the organism to have a life process that kindles itself and is its own self-renewal. This self-subsistent character of the organism signifies that it may have enabling conditions, but that it has a self-activity of its own whose process is determined by itself. The organism has definite limits, including those that reflect its particular species being, but these limits are imposed upon it by its own life process.

One is tempted to equate this self-subsistence to a physical shape that upholds itself in resisting external forces. Hegel reminds us, however, that chemical reaction, which life incorporates, is a non-superficial, thoroughgoing transformative process involving the dissolution of shape . [46] The living organism therefore cannot be a crystal , nor can the growth of an organism be equated with the growth of a crystal , whose accretions are just as devoid of self-renewing process as the superficial movements of magnets or the discharges of electricity. In chemical process and in the organism the shape of particular materials is continually transformed and in a sense continually losing itself. In the organism as a whole, a self-activity is maintained through the continual transformation and exchange of materials. This process can be described as

having an infinite form insofar as its identity is not established by its contrast with something else or by being determined by something else. Rather, the organism maintains its own identity in and through its own life process, which continually renews itself as the product of its own constitutive activity. In this way, the organism is self-limiting on the basis of the contingent integration of chemical processes from which it first emerges. By negating external determination, the organism overcomes the finitude of chemical process and retains a non-finite character, which contains within it the finite processes of chemical relations, together with the mechanism and physical processes that chemical reality itself incorporates. [47]

Notes

1. Hegel, *Philosophy of Nature* , §323–325, pp. 220–232.

2. Hegel, *Philosophy of Nature* , §324, p. 222.

3. Hegel, *Philosophy of Nature* , Remark to §324, p. 221, Zusatz to §324, p. 229.

4. Hegel, *Philosophy of Nature* , §324, p. 221.

5. Hegel, *Philosophy of Nature* , Zusatz to §323, p. 221.

6. Hegel, *Philosophy of Nature* , §323, p. 220, Zusatz to §323, p. 221.

7. Hegel, *Philosophy of Nature* , Remark to §324, p. 224.

8. Hegel, *Philosophy of Nature* , Zusatz to §324 p. 224.

9. Hegel, *Philosophy of Nature* , §324, p. 222.

10. Hegel, *Philosophy of Nature* , §330, p. 244.

11. Hegel, *Philosophy of Nature* , §324, p. 229.

12. Heisenberg describes these two types of chemical bonding, describing the latter form as “valency” bonding. See Heisenberg, *Physics and Philosophy*, p. 127.

13. Hegel, *Philosophy of Nature* , §338–342, pp. 277–303.

14. Hegel, *Philosophy of Nature* , §326, p. 326, Zusatz to §326, p. 233.

15. Hegel, *Philosophy of Nature* , Zusatz to §326, p. 233.

16. Hegel, *Philosophy of Nature* , Zusatz to §326, p. 233.

17. Hegel, *Philosophy of Nature* , §327, p. 236.

18. Hegel, *Philosophy of Nature* , §327, p. 236.

19. Hegel, *Philosophy of Nature* , §327, p. 236.

20. Hegel, *Philosophy of Nature* , §329, p. 241, Zusatz to §329, p. 242.

21. Hegel, *Philosophy of Nature* , Zusatz to §328, p. 239.

22. For an analysis of the development of syllogism, which thinks through Hegel's account in the *Science of Logic* , see Richard Dien Winfield, *From Concept to Objectivity: Thinking Through Hegel's Subjective Logic* (Aldershot, UK: Ashgate, 2006), pp. 107–130.

23. See Evan Thompson , *Mind in Life* (Cambridge, MA: Harvard University Press, 2007), pp. 91–127, for a discussion of these biological theories of autopoiesis.

24. Hegel, *Philosophy of Nature* , Zusatz to §326, p. 235.

25. Aristotle , *Physics*, Book VII, Chap. 2, 244b2–245a16, in *The Complete Works of Aristotle* , I, p. 411; *Physics*, Book VIII, Chap. 7, 260b1–14, in *The Complete Works of Aristotle* , I, p. 435; *Physics*, Book VIII, Chap. 7, 260a27–260b4, in *The Complete Works of Aristotle* , I, p. 435.

26. Hegel, *Philosophy of Nature* , §328, p. 238.

27. Hegel, *Philosophy of Nature* , §330, p. 244.

28. Hegel, *Philosophy of Nature* , Zusatz to §333, p. 263.

29. Hegel, *Philosophy of Nature* , §330–333, pp. 244–263.

30. Hegel, *Philosophy of Nature* , §328, Zusatz to §328, pp. 238–240.

31. Hegel, *Philosophy of Nature* , Zusatz to §328, p. 241.

32. Hegel, *Philosophy of Nature* , §330, pp. 244–245.

33. Hegel, *Philosophy of Nature* , Zusatz to §330, pp. 250–256.

34. Hegel, *Philosophy of Nature* , §331, p. 246.

35. Hegel, *Philosophy of Nature* , §332, p. 259.

36. Hegel, *Philosophy of Nature* , §333, p. 261.

37. For a detailed treatment of the forms of judgment and the forms of syllogism, and why there can be no fourth form of syllogism, see Richard Dien Winfield, *From Concept to Objectivity: Thinking through Hegel's Subjective Logic*, pp. 89–128.

38. Hegel, *Philosophy of Nature* , Zusatz to §335, p. 269.

39. Hegel, *Philosophy of Nature* , Zusatz to §335, p. 269.

40. Hegel, *Philosophy of Nature* , §335, p. 269.

41. Hegel, *Philosophy of Nature* , Zusatz to §335, p. 269.

42. Hegel, *Philosophy of Nature* , §336, p. 270.

43. Hegel, *Philosophy of Nature* , §336, p. 270.

44. Hegel, *Philosophy of Nature* , Zusatz to §336, p. 271.

45. Hegel, *Philosophy of Nature* , §336, p. 270.

46. Hegel, *Philosophy of Nature* , Zusatz to §336, p. 271.

47. For further exploration of the a priori universal biology that follows upon a priori chemistry and conceives the fundamental forms of life in the universe, see my forthcoming sequel: *Conceiving Life after Aristotle , Kant, and Hegel: The Philosopher's Guide to Life in the Universe*.

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